TRANSACTIONS

of the

American Society for Steel Treating

Vol. VIII November, 1925 No. 5

WHO ARE THE STEEL TREATERS?

FOR those who did not have the opportunity of reading the special editions of *Daily Metal Trade* which were published during the week of the Seventh Annual Convention of the Society, and devoted especially to the convention, the following editorial from the Thursday edition may be of considerable interest. The editors of *Daily Metal Trade* are in close contact with the steel business and their vision therefore is broad.

"Gathered in Cleveland this week is a most remarkable assemblage of extraordinary men. They have come from far and near, only a few from each community—it can support only a few of them. But they are fundamental to it. In most cases there would be no community but for them and their work. Yet these very men would be the first to deny emphatically that anything of the extraordinary clings to them. They do not know it. Others do. And are willing to talk about it. Hence this little word.

"To judge from reading most public prints, the really great 'steel-makers' of the country are Gary, Grace, Schwab, Topping, Huston, Block, Farrell, Donner, Campbell, King, Glass, Glenn, Welborn, Verity and a host of as widely quoted steel trade authorities. Yet these men are not steel-makers at all. Oh, well, time was when some of them used to make steel—but that was years ago. Since then they have reformed and now are the financial wizards, the shrewd and far-sighted executives who keep the particular machine together and the axles well greased so the wheels will continue to go on, forever turning out more millions of tons of steel each year than in the preceding twelvemonth.

And then they sell it. And get back real money for it. And then make more steel. And sell that. And still more—

"This week the real wizards of the steel business are all gathered in Cleveland. They take a bit of the common garden variety of steel, pick it to pieces, pile the fragments on the bottom of a furnace, throw in a few dabs of this, a few pinches of that, melt it all down, roll it and, lo and behold—it isn't the same thing at all that it once was. It is something far different. Then they pick a sample of that to pieces to see what is left inside it. They take another sample and heat it a certain number of degrees Fahrenheit or Centigrade or something like that, and then they knead it until the grain runs the other way, or stands on end or does something else just as queer. And while it still is white-hot, or cherry-red or straw-yellow or some other hue of the rainbow, they plunge some of it into water, or into oil or into salt—and then see what has happened to that once common steel! Whereas once it seemed destined to go into a tin can, or an automobile light or an oil pipe line—now it has become an aristocrat. It can withstand as forged armor plate the tremendous impact of a missile from a rifle that shoots 20 miles. Or as another forging it confines under tremendous heat and pressure the crude petroleum going through the weirdest 'cracking' processes. Or in still other forms it stands right up under terrific torsion strains that would have reduced ordinary steel to fragments, or takes and keeps a cutting-edge such as fifty years ago never would have been dreamed possible.

"Who are these wizards? They are the men who reach into the bowels of an electric furnace into which they previously had tossed a bunch of 'junk' and then well manicure it, and who pull out some of the most wonderful metals with the most unheard of properties and potentialities with all the nonchalance that Keller or Hermann or some other prestidigitator pulls out a kicking rabbit or a squealing pig from under the coat collar of his astonished stage victim. They look plain enough sort of men. If one saw them around the plant they would appear very much as any sort of workmen.

"But one finds them far different if he is lucky enough to pry one of the fraternity loose from his electric furnace long enough to get him talking. Stripping away his technical language, which sounds as entertaining at first as Chocktaw or

Hindoostanee, one finds—that he is a 'nut'? Well, a first class 'nut' is one who spends his life digging into the remote aorist cases of the fragments of an archaic Greek verb. This fellow, on the other hand, spends considerable of his life digging into the interior of a bit of steel which if, in a raw state, it slipped to the floor, might be shattered to bits like brittle glass, but which when put through its 'treatment' paces, emerges as something so entirely different as that it will withstand the most tremendous shocks, strains or abrasives imaginable. And the results, tangible at least, lie not in the piles of stock steel—rather in the piles of blue-print data sheets upon his desk, each figure among the myriads embraced therein costing the company that employs him a tidy sum. And to furnish that tidy sum with which to fill those data sheets causes the Garys, the Graces, the Schwabs and the other executives to walk the floors days and nights in the effort to escape the clutches of the sheriff. Those often-accursed data sheets, however, furnish the 'know' whereby these plant wizards can and do go right back to their furnace day after day, mix other batches of queer stuffs and get the same astounding results regularly. Results, mind you, that stand the steel world upon its head. Results that are just as certain in the metallurgical and mechanical world as they can pledge their immortal and honorable souls shall be just that very thing.

"Who are these metallurgical 'nuts' who each day are steadily sliding the skids under the ordinary, common variety of steel? Who are these moles who are burrowing under and wrecking almost daily some huge oldtime proud works here and there throughout the country, supplanting them with something else that turns out something different but about whose performance every steel man almost goes 'crazy'?

"They are the members of the American Society for Steel Treating, now meeting in Cleveland in annual convention. Their wonderful tools are being shown in the astonishing exhibition hall. There is not a real 'nut' among them. They, after all, are the most practical because the widest-visioned men in the steel business. They peer far into the future and they know what the steel of the next quarter century-distant will be and have some vision of what it will do. They are the real steel-makers."—*Daily Metal Trade*, September 17, 1925.

SECTIONAL MEETINGS

THE American Society for Steel Treating was one of the first of the technical societies to establish regional or sectional meetings. It was formerly a policy to select some single locality and concentrate there with the annual meeting. The American

HOTEL STATLER
Headquarters for Winter Sectional Meeting, January 21, 22, 1926

Society for Steel Treating early realized that a large number of its members did not always find it convenient or possible to attend the annual meeting and consequently their contact with the spirit

and good-fellowship side of the Society was lost. So winter and spring sectional meetings were established at which programs of two-days duration are held. This forms a basis where 300 to 400 of the members in that region get together, renewing acquaintanceship, hearing technical papers read and discussed, inspect manufacturing plants in that city and observe the spirit of co-operation and assistance which is so pronounced in the American Society for Steel Treating.

The sectional meetings have been growing in importance and have been so distributed as to make a proper balance between the sectional and annual meetings. In 1926, for instance, the winter sectional meeting will be held in Buffalo, January 21 and 22, the spring meeting will be held in Hartford probably early in June, while the annual Convention and Exposition will be held in Chicago in September. In that way all members of the Society in all sections are brought in close touch with its activities during the year. The Board of Directors always has one of their regular meetings on the day preceding the two-day sectional meeting and then have the opportunity for the two remaining days of being in close contact with the members so that they may have and feel the pulse of the membership as to their wishes.

The winter sectional meeting in Buffalo is rapidly approaching a finished stage. A number of high grade papers have already been secured and others are now in preparation for presentation at that time. The members of the Buffalo chapter under the able direction of Chairman G. J. Armstrong have already had several meetings and are formulating details for making the Buffalo event an exceptionally successful one.

The tentative program is as follows:

Thursday, January 21

9:00 to 10:30 A. M.—Registration.
10:30 to 12:00 M.—Technical Session.
1:30 P. M.—Plant Inspection.
6:30 P. M.—Dinner Meeting, Statler Hotel.

Friday, January 22

9:30 A. M.—Technical Session.
1:30 P. M.—Plant Inspection.
7:30 P. M.—Technical Session.

Saturday, January 23

Trip to Niagara Falls.

UNAUDITED PROFIT AND LOSS STATEMENT AMERICAN SOCIETY *for* STEEL TREATING

From January 1 to September 30, 1925

INCOME

Gross Dues	$ 28,592.60	
Transactions Advertising	25,427.34	
Transaction Sales	1,357.65	
Bindery Account	730.50	
Discounts Received	340.86	
Interest	1,053.64	
Data Sheets	1,766.35	
Transactions Book Account	263.64	
Miscellaneous Receipts	1,253.57	
		$ 60,786.15

EXPENSES

Discounts Allowed	$ 215.59	
Bindery Account	1,249.50	
Reprints	1,167.98	
Data Sheets	2,280.25	
Library	175.76	
Transactions Advertising Expense	606.57	
Transactions Book Account	177.02	
Miscellaneous Expenses	181.90	
Transactions	20,893.62	
Secretary's Office	8,339.65	
President's Office	488.07	
Treasurer's Office	1,454.55	
Director's Expenses	908.97	
National Committees	3,335.38	
Sectional Meetings	613.33	
Local Chapters	11,680.02	
Incidental Expense	55.00	
		$ 53,823.16
Excess of Income over Expense		$ 6,962.99

BALANCE SHEET

As of September 30, 1925

ASSETS

Commercial Account Cleveland Trust Co.	$ 8,425.91	
Savings Account Cleveland Trust Co.	10,198.12	
Savings Account Equity Savings & Loan Co.	21,885.20	
Savings Account Union Trust Co.	1,148.66	
Bond Investments	41,000.00	
United States Treasury Certificates	2,165.00	
Accounts Receivable for Advertising	6,964.53	
Accounts Receivable Miscellaneous	2,069.57	
Office Furniture and Fixtures	1,016.87	
1924 Convention Accounts Receivable	20.00	
1925 Convention Prepaid Expenses	18,841.82	
Inventory, January 1, 1925	2,631.00	
1926 Convention Prepaid Expenses	284.78	$116,651.46

LIABILITIES

Accounts Payable		$ 849.72	
Reserve for Dues Paid in Advance		10,000.00	
Reserve for Doubtful Accounts		1,000.00	
Permanent Convention Reserve		20,000.00	
Advance Receipts 1925 Convention		46,722.10	
H. M. Howe Medal Fund		3,000.00	
Surplus, January 1, 1925	$ 28,116.65		
Profit from January 1, to September 30, 1925	6,962.99	35,079.64	$116,651.46

COMPARATIVE SLOW BEND AND IMPACT NOTCHED BAR TESTS ON SOME METALS

By S. N. Petrenko

Abstract

Comparative impact and slow bend tests on notched bars were made on some non-ferrous alloys and steels in order to determine whether the slow bend test may be used as a substitute for, or as a useful addition to, the impact test. The tests were made in an Izod pendulum type impact machine of 120 foot pounds capacity and a Humfrey slow bend machine of about 100 foot pounds capacity, on the cantilever beam type specimens, having a 10 by 10 millimeter section.

The effect of the shape of notch on the impact and on the slow bend values was also studied.

The slow bend test gave values lower than the impact for non-ferrous materials and higher than the impact for steels.

Wherever the variation of the notched bar values is present in the specimens made of the same material, whether this variation is due to the shape of notch or to its position in respect to the rolling direction, or to the variation in the notched bar properties of a material, the slow bend test gives results comparable with those of the impact test, but it is less responsive to these variations than the impact test. By means of a bending moment diagram the slow bend test gives some values which are related to the tensile yield point and to the tensile strength of the materials.

It is, however, less convenient than the impact test for the ordinary routine practice.

The metallographic examination has shown that the variation in the individual values of notched bar tests made on the same sample and under identical conditions can, in many cases, be directly accounted for by the structural condition of metal and by the presence of inclusions instead of being considered as test errors which are beyond the control of operator.

An empirical formula gives the slow bend or the impact value as a sum of two terms, one of which is

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proportional to the radius of the notch and the other to the square of the net thickness of the specimen.

For brittle materials the impact and the slow bend values are greatly affectel by the radius of the notch, but are little affected by the net thickness of the specimen. For tough materials the opposite is true.

Introduction

SOME machinery parts, as well as parts of some larger engineering structures, are often subjected to sudden shocks which may stress the material above the ordinary stresses for which the part is designed.

Experience teaches us that the effect of such shocks is more severe when a structural member has sharp re-entrant angles. In the immediate vicinity of such places the stresses may rise far above those for which the member is designed. The abnormally high stresses produced by a suddenly applied force are particularly dangerous in a material which has not been correctly heat treated, and which, as the result, has a peculiar property of shock brittleness. In this case, the ordinary static tests cannot reveal the inherent weakness of such material. Hence, the necessity of an impact test. The most convenient of such tests and one in which the material approximates the most dangerous possible conditions is a transverse impact test on notched specimens. In this test the total energy absorbed by a standard specimen is measured. Due to the extremely short period of time during which the deformation occurs, it is inconvenient to obtain any other information in an impact test. It has been claimed, however, that a slow bend test on a notched specimen may give the same information that an impact test gives and, moreover, it may show some other properties of material which cannot be easily shown in an impact test. Among these properties, for example, is the value of bending moment corresponding to any given angle of bend.

Scope of the Work

The relation between the manner in which the force is applied and the energy absorbed by a notched specimen has been the subject of a number of investigations. Most of these investigations were conducted on ferrous alloys. The list of these works

is given in the bibliography appended to this paper. In order to determine whether a slow bend test may be used as a substitute for an impact test or as a valuable addition to it, and in order to determine also its practicability, the Bureau of Standards has made parallel impact and slow bend tests on some materials, mostly non-ferrous alloys. The effect of the shape of the notch on the impact and on the slow bend values has also been studied to determine whether this effect may be expressed by a definite law.

In series I of these tests a comparison was made of the impact and of the slow bend values obtained from a large number of tests (in Table II and in other places materials used in this series are marked A).

In series II tests the effect of the shape of the notch on the impact and on the slow bend values was studied.

Acknowledgment

The materials used in these tests were given by the following manufacturers:

1. American Brass Company
2. International Nickel Company
3. Aluminum Company of America
4. American Rolling Mills Company
5. Carpenter Steel Company
6. Bausch Machine Tool Co.
7. Reading Iron Company.

The writer is also indebted to Samuel Epstein for a metallographic examination of the materials used in these tests. His report is given in full in this paper under the heading of Metallographic Examination.

Testing Machines

The Humfrey slow bend machine which was used in this investigation is shown in Fig. 1. The bending moment is applied to the specimen which is held in a vise at H, by means of a flexible arm A. Parallel to this arm and immediately above it is a rigid arm B, along which slides a pencil carrier, drawn by a wire, the other end of which is fastened to the post C. The

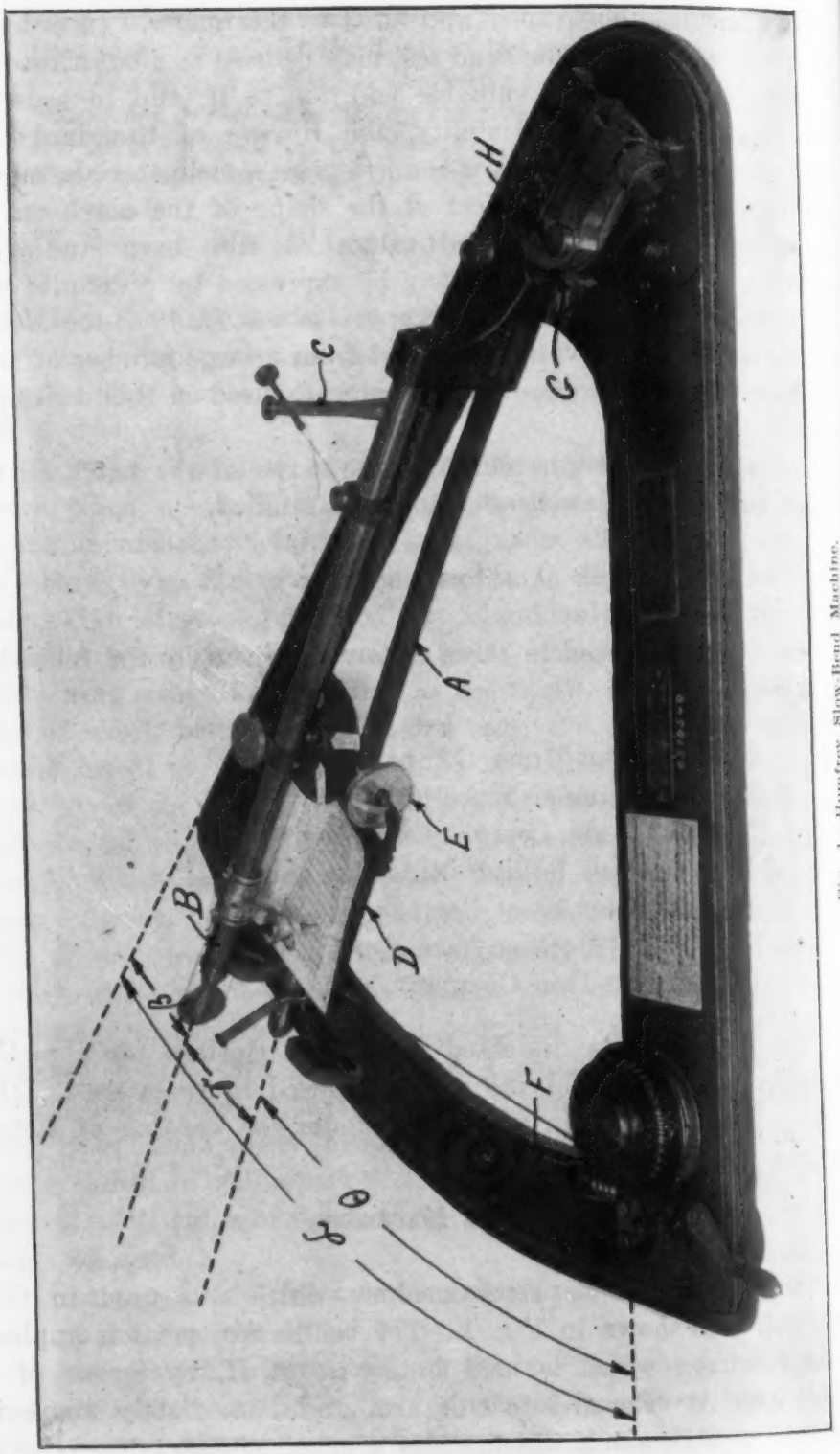

Fig. 1—Humfrey Slow-Bend Machine.

displacements of the pencil along the arm B are proportional to the angle through which the specimen is bent. The flexible arm carries a plate D for the paper on which the bending moment diagram is drawn.

As the deflection of arm A is proportional to the bending moment, the ordinates of the diagram measure the bending moment. Thus the area of the diagram represents the energy absorbed by the specimen. Since it would be inconvenient to measure the energy from this diagram, owing to the fact that the ordinates are not straight lines, and the scale for the ordinates changes with the angle of bend (see Fig. 3), a mechanical integrator E is used to record the energy absorbed by the specimen at any instant during the test. The capacity of this machine is about 100 foot pounds, and the maximum angle through which a specimen is bent is about 35 degrees. The rate of bending in all these tests was about 2 degrees per second.

Fig. 1—Humfrey Slow-Bend Machine.

The impact machine, which is shown in Fig. 2, was an Izod pendulum type machine having a capacity of 120 foot pounds. The striking velocity of the hammer was 12.44 feet per second. In this machine a specimen is bent through an angle of about 60 degrees.

The Izod impact machine was chosen for these comparative tests, as this machine requires the same size of specimen as the slow bend machine. In each of these machines the specimen is fixed at one end and the force is applied at the other.

Interpretation of a Slow Bend Diagram

Typical diagrams are shown in Fig. 3. The diagrams obtained in slow bend tests belong to one of the two types shown in Fig. 4, type 1 representing ductile and type 2 brittle materials.

Owing to the presence of the notch in the specimen and the resulting high concentration of stresses a slow bend diagram is not directly comparable with a diagram which may be obtained in a transverse or tensile test. However, some values given by the slow bend diagram may be correlated with certain tensile or transverse values.

It is obvious that these bending diagrams are similar to the stress-deformation diagrams for tensile or transverse tests. The portion AB of the curve corresponds to the elastic deformation of

the specimen, and near the point B plastic deformation begins to take place, i. e., the specimen remains bent when the bending moment is removed.

The portion of the diagram BC corresponds to the period of plastic deformation of the specimen. The resistance of the speci-

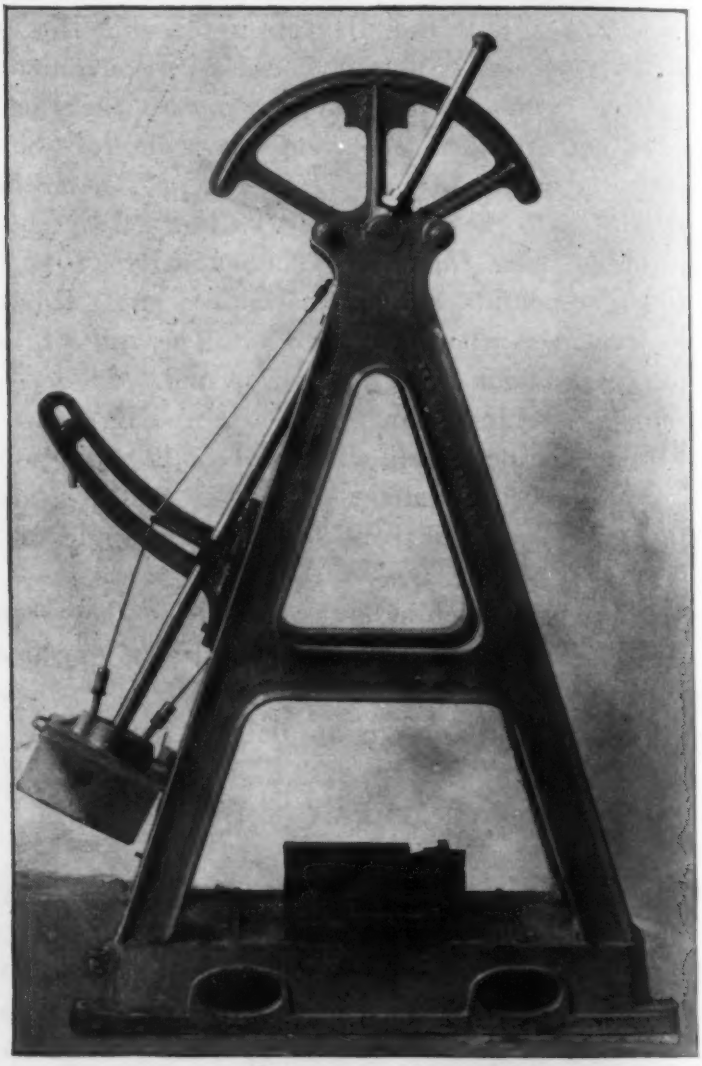

Fig. 2—Izod Impact Machine

men during this period changes but little. Soon after the maximum bending moment is reached the resistance of the specimen begins to drop off more or less rapidly. It is accompanied by the appearance of a crack or cracks at the bottom of the notch. The brittle materials are characterized by a rapid extension of the

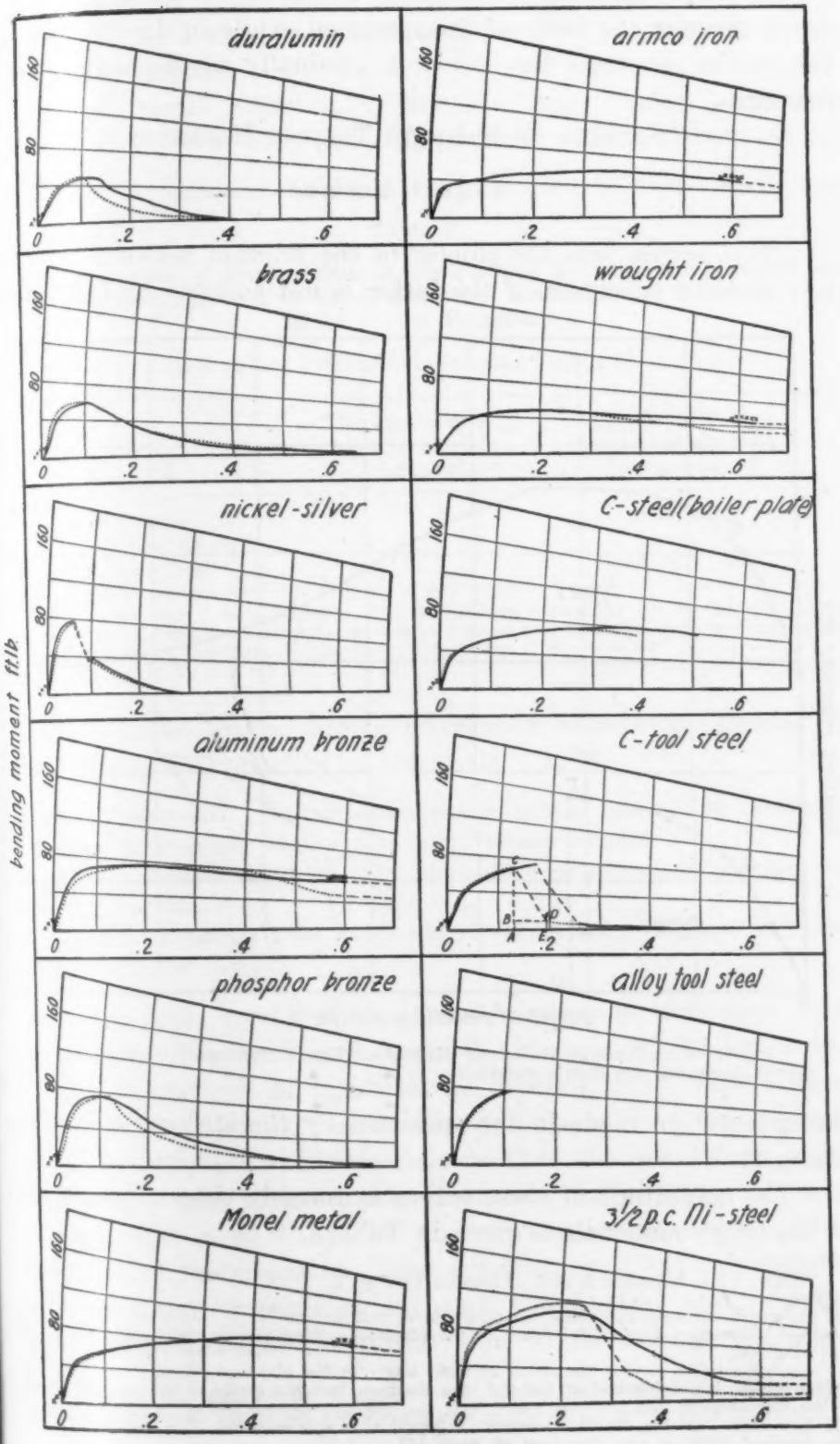

Fig. 3—Typical Slow-Bend Diagrams for "Standard" Notch.
(See foot note on page 526)

crack through the body of the specimen, while in ductile materials the cracks penetrate the specimen gradually as the angle of bend increases.

Sources of Error in Testing Machines

Impact Machine

Test errors are due chiefly to the friction between the hammer and the specimen, if the latter is not entirely broken, and to

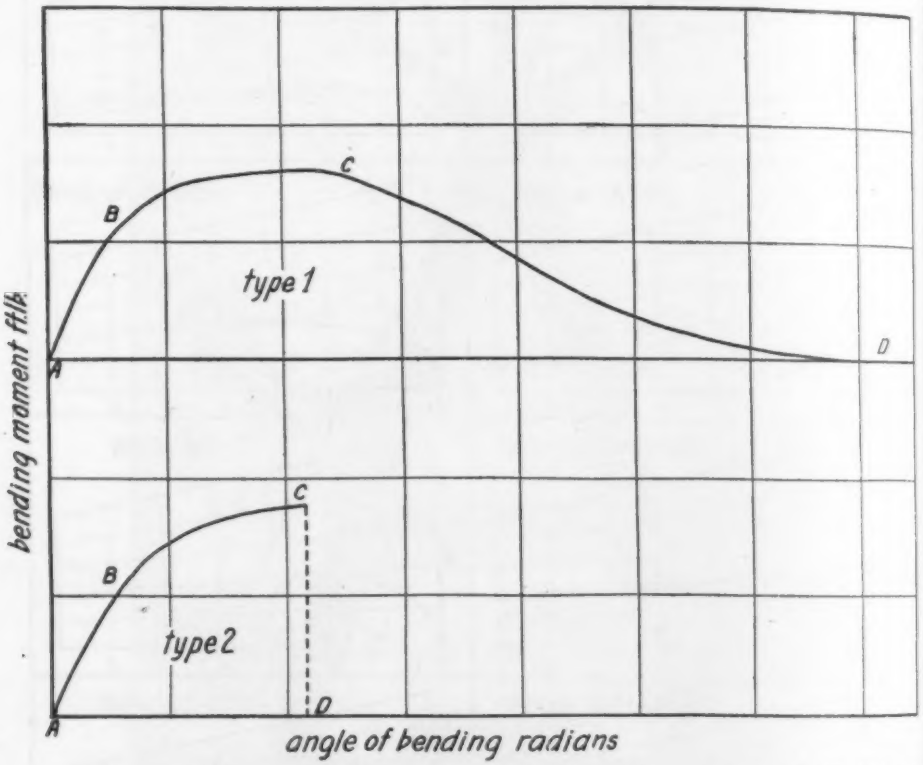

Fig. 4—Two Types of Slow-Bend Diagrams. Type 1 Represents the Ductile Materials. Type 2 Represents the Brittle Materials.

the indentation made in the specimen by the striking edge of the hammer.

The magnitude of these errors as roughly determined on some of the tough materials is given in Table I.

NOTE:—The following is part of caption for Fig. 3.

All the specimens were cut along the direction of rolling.
———— Specimens having the notch in the plane of rolling and at right angle to the direction of rolling
---------- Specimens having the notch at right angle to the plane of rolling.
Crosses at the beginning and at the end of a diagram indicate errors of the machine described at the top of page 531.
The dash lines indicate the displacement of pencil at a sudden break of a specimen.
The involved error is also described on page 531.

The sum of these errors is negligible in most cases, but, as shown in Table I, may be as high as 5 per cent of the total energy for tough materials.

As the terms "ductile," "brittle," and "tough" are used often in this paper, they are defined here. These definitions are

Table I

Approximate Loss of Energy Due to the Friction Between the Hammer and the Specimen and to the Indentation Made by the Striking Edge of the Hammer

(All values determined for standard notch)

Material	The loss of energy due to friction, foot pounds*	The loss of energy due to indentation, foot pounds**
Monel metal	4	about 1.0
Aluminum bronze ..	2	about 1.0
Wrought iron	1.5	about 1.0

*Determined on a specimen after it had been tested and left in the machine.
**Determined by dropping a weight from a height necessary to produce indentation equal to that produced by the striking edge of the hammer.

taken from the United States Bureau of Standards Circular No. 101, "Physical Properties of Materials," 1924.

Ductile materials are those which are capable of undergoing considerable permanent deformation while subjected to tensile stresses.

Brittle materials are those which show little permanent deformation when stressed to rupture.

Tough materials are those which will withstand heavy shocks or will absorb a large amount of energy.

A protector made of hard steel, similar to that used in the impact tests of wood, might diminish this part of the lost energy.

Another source of error is the dissipation of impact energy through vibrations in the machine. This subject was discussed by R. Southwell,[1] who recommends that the pendulum be suspended by ropes to avoid the dissipation of energy. It is also believed that a part of the energy is dissipated through the vibrations of the specimen. The appearance of the upper portion of some tough specimens, such as nickel steel and aluminum bronze, indicates that the initial blow of the hammer is followed

[1] "Note on the Application of Dimensional Theory to Notched Bar Impact Tests," Aeronautical Research Committee, Reports and Memoranda No. 732 (M. 2), January, 1921.

by a succession of light blows which are due to the vibrations of the specimen. The loss of energy due to these repeated blows is, however, small.

Slow Bend Machine

In the type of machine used in these tests, the tension of a coil spring stretched between the end post (C) and the integrator increases as the angle of bend increases, and the work, which is required to stretch the spring, is added to the reading of the integrator.

For the specimens which break at a comparatively small angle of bend, say, not more than 15 degrees, this error may be disregarded. But for the larger angles of bend a correction should be made. Its value may be found by determining the work of stretching the spring with no specimen in place. In these tests it was about 1.5 foot pounds for the maximum angle of bend, i. e., from about 1 per cent for tough materials like Monel metal and aluminum bronze to about 4 per cent for brass.

The maximum angle through which the rigid arm B (see Fig. 1) may be rotated is α. But in view of the deflection of the flexible arm A, the angle through which a specimen may be bent is less than α. In a test, when the arm (A) is brought to (F) and angle Θ becomes equal to zero we have: $\alpha = \beta_{max} + \gamma$. As the angle α is constant it is evident that β_{max} depends upon γ. For materials which require large bending moments (large γ) β_{max} will be smaller than in the case of materials which require small bending moments. For most materials the value of β_{max} is from 30 to 40 degrees. The angle of bend in the Izod impact machine is about 60 degrees and a correction should be made for slow bend specimens which are not entirely broken, in order to make the results obtained by two methods, more nearly comparable. The energy for the angle of bend between that obtained in the slow bend machine, and 60 degrees, was calculated and added to the slow bend value.

This was done on the assumption that the energy absorbed in slow bend is proportional to the angle through which the specimen is bent.

This method was used because the diagrams of aluminum bronze, Armco iron, wrought iron and Monel metal, to which it was applied, were of a horizontal type, as can be seen in Fig. 3.

Table II—Chemical Composition of Tested Metals

Material*	C	Mn	Si	P	S	Fe	Mg	Ni	Cr	W	Al	Cu	Pb	Zn
Duralumin A	....	0.58	0.54	.....	.....	0.58	0.60	....	....	....	(1)	4.0	..	....
Duralumin B	....	.48	.28	.....	.....	1.0	.46	....	....	....	(2)	3.7	..	....
Duralumin C	....	.49	.32	.....	.....	.9	.36	....	....	....	(3)	3.7	..	....
Brass A	....	...	...	.....	.....	(4)	...	....	....	....	...	65.3	(5)	34.6
Brass B	....	...	...	.....	.....	(4)	...	....	....	....	...	67.0	(5)	32.8
Aluminum bronze	....	...	...	.....	.....	...	...	....	....	....	7.9	92.0	..	....
Phosphor bronze	....	...	...	0.17	.....	(4)	...	....	....	....	...	95.2	..	4.4
Nickel silver A	....	.32	...	.....	.....	(4)	...	18.2	....	....	...	64.0	..	17.4
Nickel silver B	....	.15	...	.....	.....	(4)	...	18.3	....	....	...	64.4	..	16.9
Monel metal A	0.27	2.27	.13	.....	0.014	2.55	...	67.2	....	....	...	27.5	..	....
Monel metal B	.22	1.8	.04	.....	.002	2.5	...	68.0	....	....	...	27.5	..	....
Armco iron	.02	.02	...	.....	.....	...	...	....	....	....	...	....	..	....
Wrought iron	.03	.02	...	.....	.....	...	...	....	....	....	...	....	..	....
Carbon steel (boiler plate)	.25	.50	.01	.007	.035	...	...	....	....	....	...	....	..	....
Carbon tool steel A	1.00	.24	.20	.013	.025	...	...	....	....	....	...	....	..	....
Carbon tool steel B	.89	.22	.19	.013	.019	...	...	....	....	....	...	....	..	....
Alloy tool steel A	.88	1.15	.255	.010	.007	...	...	....	0.50	0.40	...	....	..	....
Alloy tool steel B	.86	1.19	.23	.020	.011	...	...	....	.48	(3)	...	....	..	....
3½% nickel steel A	.44	.63	.24	.009	.027	...	...	3.50	.19	....	...	....	..	....
3½% nickel steel B	.44	.61	.24	.008	.024	...	...	3.63	.16	....	...	....	..	....

*All specimens "as received" from the mill excepting the carbon steel, which was annealed.

[1]Balance.
[2]Less than 0.1.
[3]Not detected.
[4]Less than 0.25.
[5]3,000 kilogram load.
[6]Estimated from hardness.

Table II (Continued)—Tensile Properties and Hardness of Tested Metals

Material*	Yield point	Tensile strength	Elongation in 2 inches	Reduction of area	B. h. n. (500 kg. load 10 mm. ball)
	Lb./in.²		*Per cent*	*Per cent*	
Duralumin A	42,200	61,100	15.8	17.6	113
Duralumin B	36,300	58,300	15.0	28.1	106
Duralumin C	34,900	56,950	24.2	32.5	100
Brass A	41,600	52,500	39.8	51.3	101
Brass B	52,100	57,050	26.7	50.5	118
Aluminum bronze	45,850	72,500	53.0	63.1	132
Phosphor bronze	64,450	66,350	21.2	51.5	147
Nickel silver A	58,800	64,800	18.5	35.8	136
Nickel silver B	73,900	78,450	10.7	43.3	160
Monel metal A	40,200	88,400	47.3	62.0	127
Monel metal B	44,400	88,400	45.7	61.9	134
Armco iron	35,050	45,100	35.0	67.2	89
Wrought iron	29,250	47,000	33.7	46.4	88
Carbon steel (boiler plate)	35,800	62,600	37.5	57.2	111
Carbon tool steel A	41,600	76,600	31.0	45.5	[5]132
Carbon tool steel B	40,950	76,200	35.2	55.7	[5]132
Alloy tool steel A	.....	[6]95,000	....	....	[5]175
Alloy tool steel B	59,800	102,800	22.0	36.6	[5]192
3½% nickel steel A	79,950	121,000	19.8	49.6	[5]227
3½% nickel steel B	57,000	103,000	27.0	56.5	[5]188

*All specimens "as received" from the mill excepting the carbon steel, which was annealed.
[5]3,000 kilogram load.
[6]Estimated from hardness.

The values thus obtained were probably somewhat greater than the true values. The magnitude of this error is unknown, as it depends upon the resistance of the specimen between the angles of 35 and 60 degrees. However, the great amount of resistance, which the impact specimens still possessed after being bent through an angle of 60 degrees, indicated that this error was relatively not great. The rough determination of the residual resistance of the unbroken impact specimens showed that the error was of the magnitude of about 5 per cent.

It does not seem probable that a specimen which has retained a considerable amount of resistance after being bent through an angle of 35 degrees would lose its resistance entirely between 35 and 60 degrees. If this occurred the results of the impact and of the slow bend test could not be compared.

At the end of a test, the end of the rigid arm may strike the point (G) (see Fig. 1) of the clamp holding the specimen. This is recorded by the integrator and appears in the diagram as a sudden increase of bending moment. (See Fig. 3, diagrams of aluminum bronze, Monel metal, Armco iron and wrought iron). The correction of this error is not necessary, as it is small.

The slow bend diagrams have in the beginning a small irregu-

larity (shown in Fig. 3 by the crosses), which manifests itself by the bend to the right and soon afterward by the renewed increase of bending moment. This irregularity is due to an imperfect

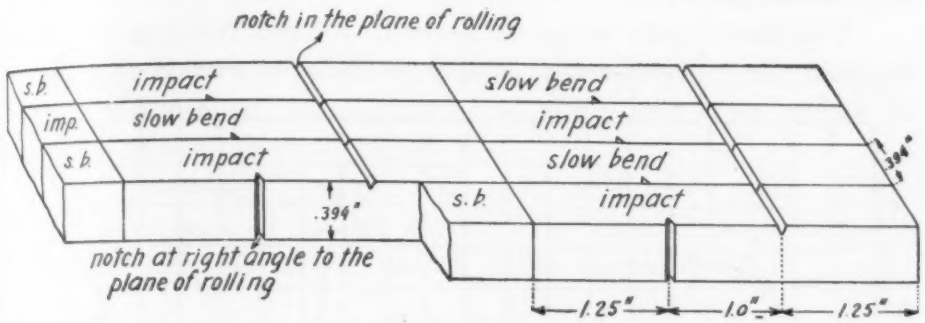

Fig. 5—Location of the Impact and Slow-Bend Specimens in a Plate.

fitting of specimen to its seat in the rigid arm (B), and being small does not need correction. The diagram, however, should be corrected by straightening the portion of it near (A), as was done in Fig. 3.

If a specimen fails suddenly, the pencil travels in an oblique direction, as though the resistance of the specimen were diminishing at a uniform rate. This may be true in a few individual cases. However, generally it is not so. It is not quite clear how the

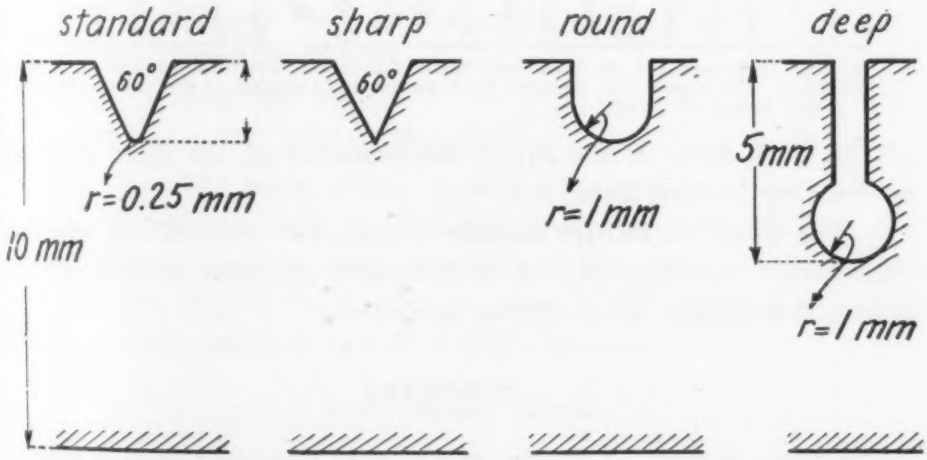

Fig. 6—Types of Notches Used in the Specimens of Series 2.

bending moment decreases with the increase of the angle of bend during this period, but it is certain that the energy absorbed by the specimen is less than that measured by the area ACDE (see Fig. 3 —diagram for carbon tool steel) and greater than that measured

by the area ABDE. The average of these two probably approximate the actual value. Evidently, the error in the value of the total energy cannot exceed the amount represented by one-half of the area BCD.

The correction is to be applied to the reading of the integrator also, because the integrator fails to record this portion

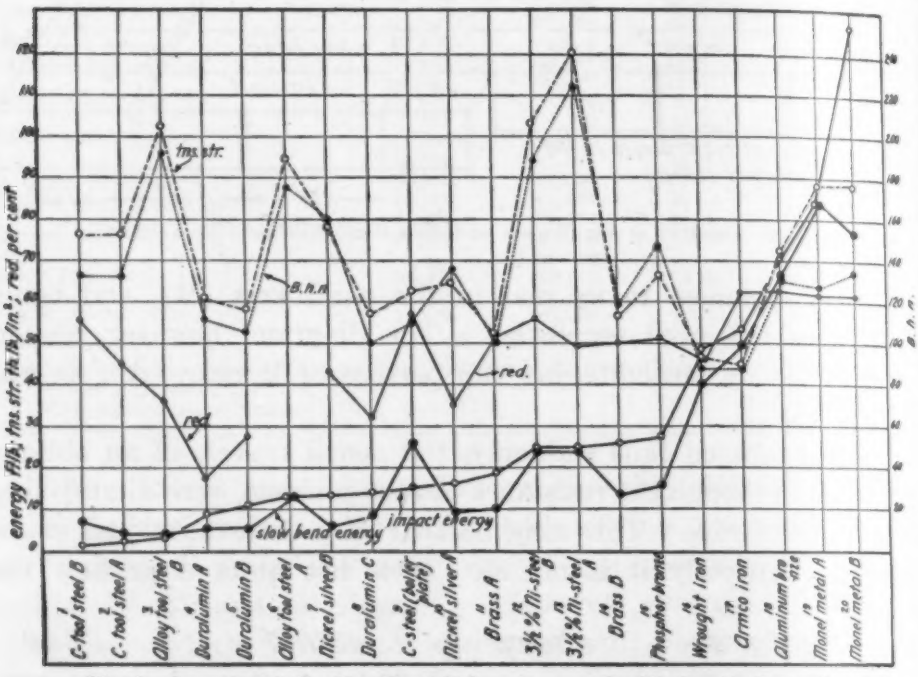

Fig. 7—Impact and the Slow-Bend Values Compared with Tensile Properties of the Materials. The Impact and the Slow-Bend Values are Averages of All Values Obtained with the "Standard" Notch.

of the work done in the rapid displacement of the rigid arm, and its reading is, therefore, low.

The shock at failure usually throws the integrating wheel off the correct reading and it is necessary to take a reading just before the failure of a brittle specimen.

Specimens

In Fig. 5 are shown the dimensions and the relative position of the impact and of the slow bend specimens in a plate. The specimens were of the cantilever type. They had notches alternately on the top of the specimen (in the plane of rolling and at right angle to the direction of rolling) and on the side (perpendicular to the plane of rolling).

For Series 1 tests (see Fig. 7, materials A) all specimens had a standard V-notch 0.079 inches (2 millimeters) deep with a 0.01 inch (0.25 millimeters) radius at the bottom. For Series 2, four different notches (see Fig. 6) were used: "standard" V-notch; "sharp" V-notch; "round" and a "deep" notch.

The notches were so chosen as to have three values for comparison of the effect of the radius of notch and three values for the effect of the depth of notch.

The "standard" notch was that ordinarily used by this Bureau for the Izod impact tests. The other three notches differed from the "standard" notch either in radius or in depth.

Materials

The following materials were used in this investigation:

a. Duralumin
b. Brass
c. Phosphor bronze
d. Aluminum bronze
e. Nickel silver
f. Monel metal
g. Armco iron
h. Wrought iron
i. 0.25 per cent carbon steel (boiler plate)
j. Carbon tool steel
k. Alloy tool steel
l. 3½ per cent nickel steel.

The chemical composition, tensile properties and hardness of these materials are given in Table II (page 529 and 530).

All these materials were supplied in the form of rectangular bars of about 2½ by ¾ inches in cross section, and about 4 feet long and were tested as received from the mill.

Results of Tests

The results of notched bar tests are given in Fig. 7 and Table III. The impact and the slow bend results are in the most cases averages of ten or more determinations; those in other tests of two or more determinations.

In all cases of slow bend the specimen was bent through as great an angle as the testing machine would permit.

Table III—Summary of the Results of Tests

(Materials marked A were used in series 1 tests and materials B and C in series 2. Each value is an average of at least four determinations.)

Material	Notch (see Fig. 6)	Impact Values		Slow-bend Values	
		Notch in the plane of rolling *Ft.-lb.*	Notch at right angle to the plane of rolling *Ft.-lb.*	Notch in the plane of rolling *Ft.-lb.*	Notch at right angle to the plane of rolling *Ft.-lb.*
Duralumin, A	Standard	10.60	7.64	6.20	4.69
Duralumin, B	Standard	13.30	9.52	6.61	5.01
Duralumin, B	Sharp	13.08	8.6	6.02	4.17
Duralumin, B	Round	16.33	13.02	9.89	8.46
Duralumin, B	Deep	8.05	7.38	5.07	4.48
Duralumin, C	Standard	16.38	12.93	10.31	7.36
Duralumin, C	Sharp	15.30	10.97	7.61	5.64
Duralumin, C	Round	20.45	17.47	12.01	10.73
Duralumin, C	Deep	10.30	9.45	5.94	5.46
Brass, A	Standard	19.45	19.15	10.58	10.32
Brass, B	Standard	27.92	24.60	14.40	13.70
Brass, B	Sharp	25.52	24.32	14.00	11.60
Brass, B	Round	32.92	34.02	19.42	22.65
Brass, B	Deep	19.72	19.90	10.97	11.47
Aluminum bronze	Standard	83.80	58.85	36.30	34.87
				[1]69.6	[1]64.0
Aluminum bronze	Sharp	81.52	57.15	35.77	33.95
				[1]67.8	[1]63.5
Aluminum bronze	Round	86.05	72.75	39.02	39.25
				[1]74.0	[1]74.9
Aluminum bronze	Deep	37.42	38.27	17.50	17.11
				[1]31.4	[1]30.8
Phosphor bronze	Standard	30.65	24.87	17.62	14.47
Phosphor bronze	Sharp	30.37	23.30	16.27	11.82
Phosphor bronze	Round	39.25	34.05	25.52	22.82
Phosphor bronze	Deep	20.90	18.82	12.90	11.55
Nickel silver, A	Standard	16.82	16.74	9.59	10.07
Nickel silver, B	Standard	14.65	12.97	6.41	6.42
Nickel silver, B	Sharp	13.85	11.17	4.92	4.97
Nickel silver, B	Round	18.05	17.12	10.62	10.49
Nickel silver, B	Deep	12.52	11.80	5.92	5.82
Monel metal, A	Standard	93.35	75.30	42.55	42.55
				[1]84.06	[1]84.06
Monel metal, B	Standard	128.7	129.2	42.27	42.57
				[1]76.5	[1]77.0
Monel metal, B	Sharp	127.7	127.8	42.42	42.57
				[1]75.9	[1]76.1
Monel metal, B	Round	129.5	131.5	44.80	45.32
				[1]82.6	[1]83.7
Monel metal, B	Deep	54.35	53.80	22.55	22.40
				[1]40.4	[1]39.9
Armco iron	Standard	54.62	52.95	29.77	30.67
				[1]49.5	[1]50.1
Armco iron	Sharp	49.55	54.02	28.82	29.47
				[1]48.1	[1]48.0
Armco iron	Round	64.65	60.97	30.65	30.45
				[1]51.1	[1]49.4
Armco iron	Deep	26.87	28.67	15.22	14.65
				[1]25.4	[1]24.2
Wrought iron	Standard	58.40	39.37	26.38	19.41
				[1]46.80	[1]33.40
Wrought iron	Sharp	54.57	35.85	22.51	17.06
				[1]39.6	[1]29.20

[1]Values corrected for the same angle of bend as in Izod machine.

Table III (Continued)—Summary of the Results of Tests

Material	Notch (see Fig. 6)	Impact Values: Notch in the plane of rolling *Ft.-lb.*	Impact Values: Notch at right angle to the plane of rolling *Ft.-lb.*	Slow-bend Values: Notch in the plane of rolling *Ft.-lb.*	Slow-bend Values: Notch at right angle to the plane of rolling *Ft.-lb.*
Wrought iron	Round	61.05	43.97	26.45	21.41
				[1]46.90	[1]36.90
Wrought iron	Deep	24.87	21.62	13.28	11.33
				[1]23.10	[1]19.50
Carbon steel, A (boiler plate)	Standard	16.33	15.22	29.03	23.37
Carbon tool steel, A (annealed)	Standard	2.28	2.13	4.58	4.43
Carbon tool steel, A (heat treated)	Standard	5.08	5.08	8.02	8.30
Carbon tool steel, B	Standard	1.65	1.55	6.78	7.75
Carbon tool steel, B	Sharp	1.08	1.02	3.95	3.94
Carbon tool steel, B	Round	6.45	7.23	21.93	22.54
Carbon tool steel, B	Deep	6.18	5.58	11.65	12.22
Alloy tool steel, A	Standard	13.33	13.18	13.60	13.55
Alloy tool steel, B	Standard	4.10	3.30	3.97	4.38
Alloy tool steel, B	Sharp	2.30	2.67	2.56	2.45
Alloy tool steel, B	Round	8.07	9.35	7.43	7.98
Alloy tool steel, B	Deep	7.77	7.25	5.57	5.10
3½ per cent nickel steel, A	Standard	25.15	25.48	24.18	24.04
3½ per cent nickel steel, B	Standard	24.97	25.27	24.03	24.55
3½ per cent nickel steel, B	Sharp	19.50	17.67	18.87	19.47
3½ per cent nickel steel, B	Round	37.52	37.82	33.52	32.00
3½ per cent nickel steel, B	Deep	24.02	25.27	16.37	17.12

The angle through which a specimen was bent in the impact machine was about 60 degress. In the slow bend machine it was about 35 degrees (it varied somewhat with the bending moment).

The slow bend values for the specimens which were not broken were corrected to give the energy for the angle of bend of 60 degrees. The method of correction is described under "errors of testing machines."

Metallographic Examination

In comparing the results of the tests it was noted that, although the results of the tensile and of the slow bend tests on Monel metal A and B were practically the same, the results of the impact test showed much lower values for Monel metal A. As there was no apparent reason for this difference, the samples of Monel metal were examined microscopically and many more inclusions were found in Monel metal A than in B. This is shown in Fig. 8. It will be noted that the grain size is about the same for both samples.

In order to determine, if possible, the relation between the structure of the metals and the results of notched bar tests, par-

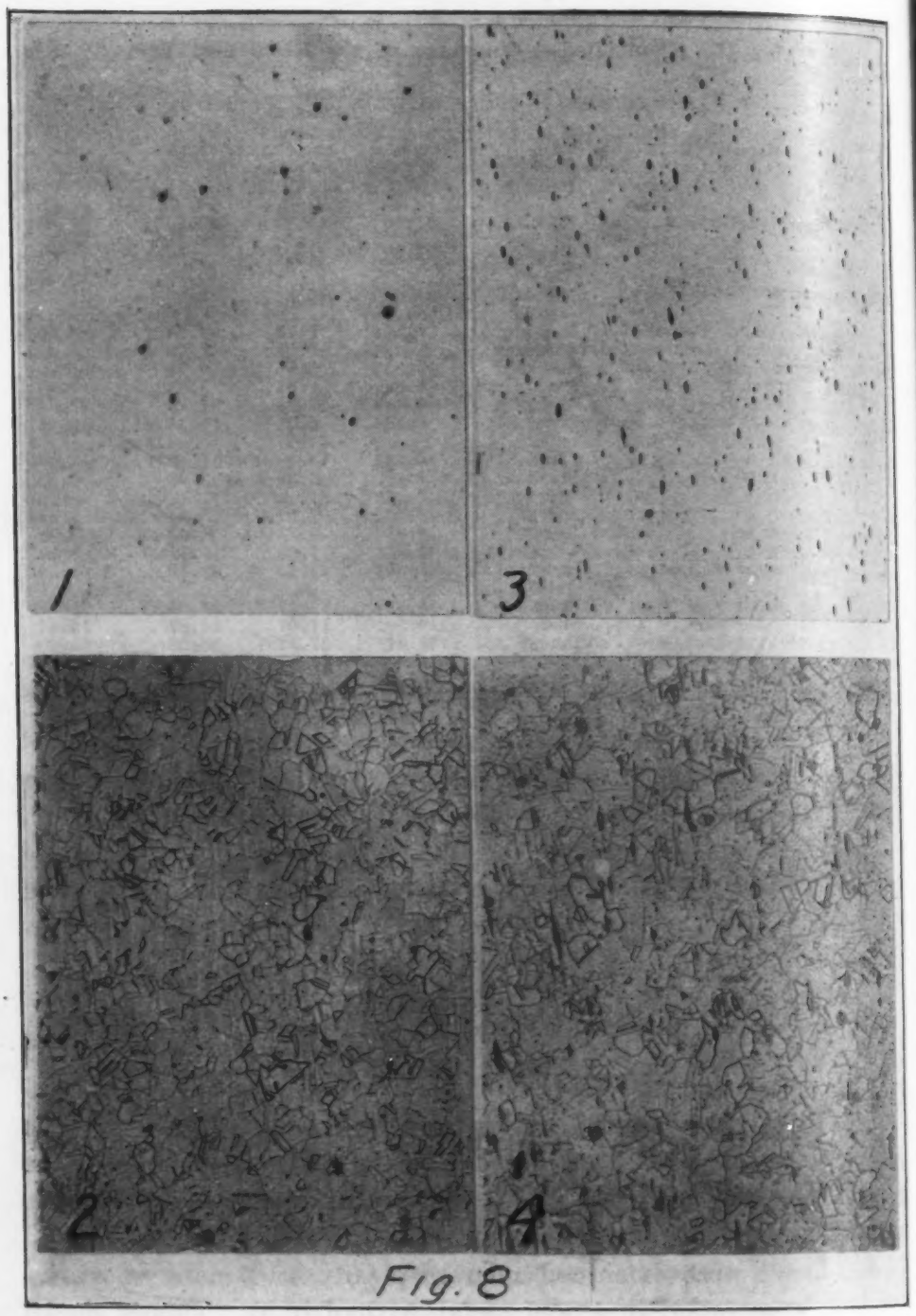

Fig. 8—Monel Metal. Magnification 100X. 1 and 3, Unetched; 2 and 4, Etched with a Solution of 30 Parts Acetic Acid, 30 Parts Nitric Acid and 40 Parts of Water. 1 and 2, Monel Metal B. Average Impact Value 129.0 Foot-Pounds. 3 and 4, Monel Metal A. Average Impact Value 84.32 Foot-Pounds. There were more Inclusions in Monel Metal A than in B. The Majority of the Inclusions were Probably of Magnesium Sulphide as was Indicated by Their Solubility in Water But Not in Alcohol. The Grain Size was About the Same for Both Samples.

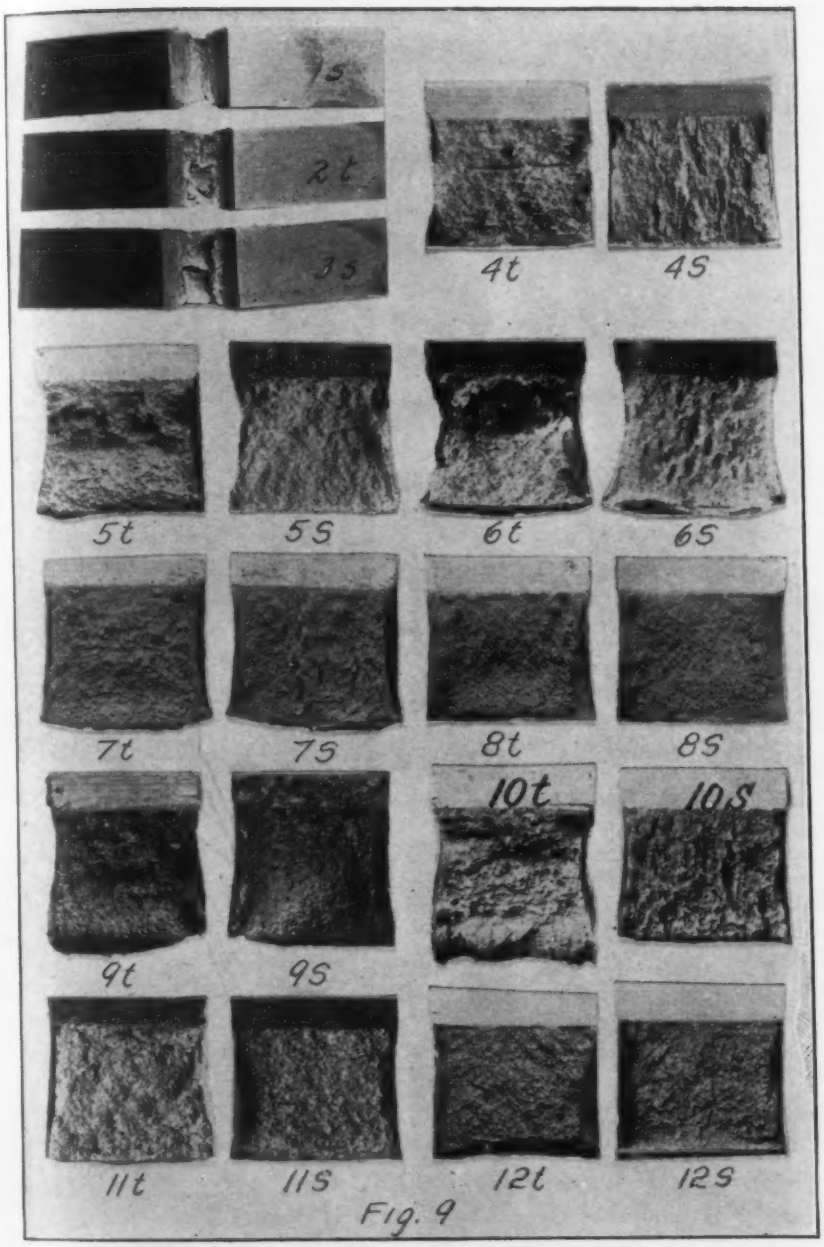

Fig. 9—Fractures of Impact Specimens. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1s. Monel Metal B, Impact Value 129.2 Foot-Pounds. 2t. Monel Metal A, Impact Value 93.35 Foot-Pounds. 3s. Monel Metal A, Impact Value 75.30 Foot-Pounds. Note the Fissure in the Fracture; Indication of Fibrousness. 4. Duralumin B, Fibrous; Impact Values; t Equals 13.30 Foot-Pounds; s Equals 9.52 Foot-Pounds. 5. Brass B, Slightly Fibrous; t Equals 27.92 Foot-Pounds; s Equals 24.60 Foot-Pounds. 6. Aluminum Bronze, Fibrous; t Equals 83.80 Foot-Pounds; s Equals 58.85 Foot-Pounds. 7. Phosphor Bronze, Fibrous; t Equals 30.65 Foot-Pounds; s Equals 24.87 Foot-Pounds. 8. Nickel Silver, Not Fibrous; t Equals 14.65 Foot-Pounds; s Equals 12.97 Foot-Pounds. 9. Armco Iron, Slightly Fibrous; t Equals 54.62 Foot-Pounds; s Equals 52.95 Foot-Pounds. 10. Wrought Iron, Fibrous; t Equals 58.40 Foot-Pounds; s Equals 39.37 Foot-Pounds. 11. Boiler Plate, Slightly Fibrous; t Equals 16.33 Foot-Pounds; s Equals 15.22 Foot-Pounds. 12. 3½ Per Cent Nickel Steel B, Slightly Fibrous; t Equals 24.97 Foot-Pounds; s Equals 25.27 Foot-Pounds.

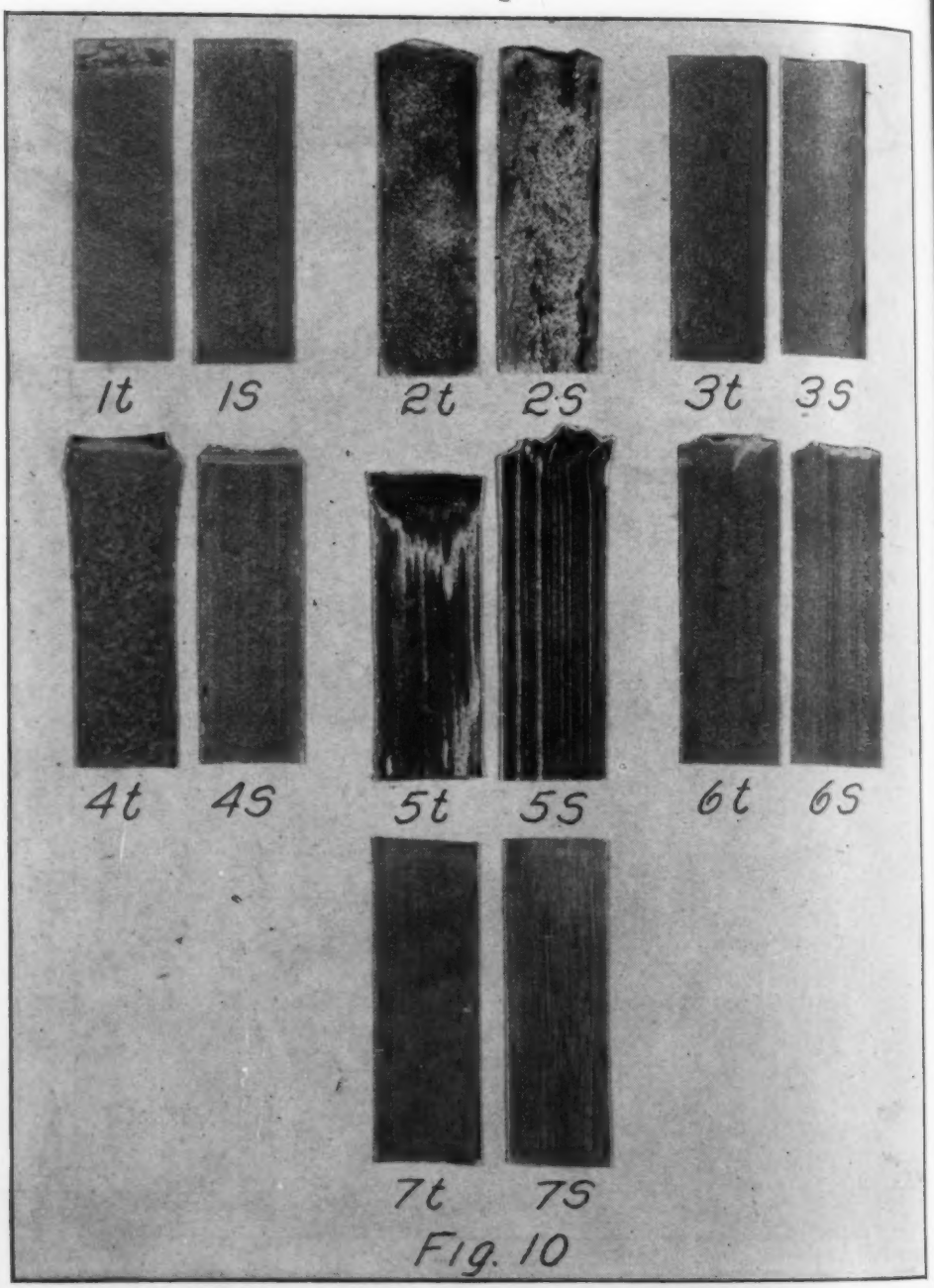

Fig. 10—Macrostructure of Some of the Metals, Showing "Fiber." Natural Size. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1. Duralumin, Etched with 10 Per Cent Sodium Hydroxide Solution. 2. Phosphor Bronze, Etched with Ammonium Hydroxide and Hydrogen Peroxide. 3. Nickel Silver, Etched with Concentrated Nitric Acid. 4. Armco Iron, Etched with Ammonium Persulphate. 5. Wrought Iron, Etched with Hot 1:1 Hydrochloric Acid in Water. 6. Boiler Plate, Etched with Hot 1:1 Hydrochloric Acid in Water. 7. 3½ Per Cent Nickel Steel, Etched with Hot 1:1 Hydrochloric Acid in Water.

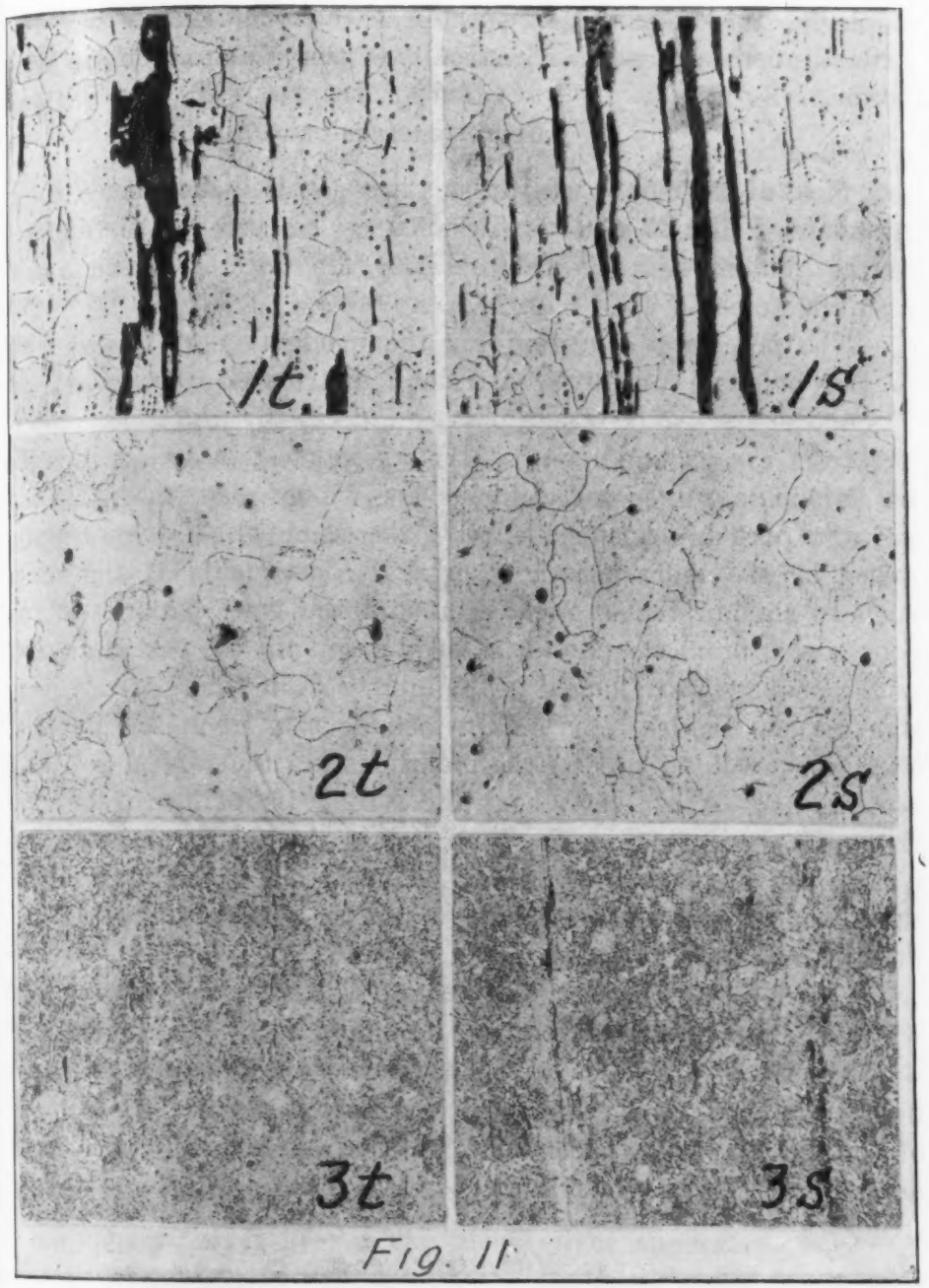

Fig. 11

Fig. 11—Ferrous Metals. Magnification 100X. Etched with 2 Per Cent Nitric Acid in Alcohol. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1. Wrought Iron, Fiber Produced by the Slag Threads. 2. Armco Iron. 3. 3½ Per Cent Nickel Steel B.

ticularly, the impact test, specimens of other metals were examined microscopically. The results of this examination are given here.

Macrostructure

Most of the metals used in this investigation show more or less pronounced fibrous structure which may be seen in the fractures of the notched bars, shown in Fig. 9, or which is revealed after a suitable etching as in Fig. 10.

The necessary condition for the production of fibrous state is the presence of any constituent distributed throughout the "ground-mass" and which possesses decidedly different properties from the ground-mass. Although in most materials it is the objectionable non-metallic inclusions which play the most important part in causing "fiber," the same effect may be produced by the characteristic structural constituents of a material such as slag in the wrought iron and the hard particles of the copper-aluminum compound in duralumin. In the cast state most of the inclusions are lodged in the interstices of the relatively large pine-tree or dendritic crystals, which develop upon solidification. During the rolling process the inclusions are rearranged into long streaks, and if soft enough at the rolling temperature, they are flattened out into thin sheets or laminations. In the plane of rolling the inclusions are merely widened out and flattened. In the plane at right angle to the plane of rolling the groups of inclusions appear as long threads.

The fibrous structure of the metal is, undoubtedly, associated with the directional differences in impact properties. Fig. 9 shows that the materials which gave the largest variation in the notched bar values, for the specimens having notches in the plane of rolling compared to the same material having notches at right angle to the plane of rolling, show the most pronounced fibrous structure.

Microstructure

The microscopic examination showed inclusions in considerable amounts, both in the ferrous and non-ferrous metals.

Ferrous Metals

In wrought iron this is, of course, more pronounced than in any of the other materials. As can be seen in Fig. 11-1, the slag

inclusions in the top section are more irregularly shaped, whereas in the side section they appear longer, thinner and, in general, more uniform. The Armco iron and the 3½ per cent nickel steel were only slightly fibrous.

Non-Ferrous Metals

Among the non-ferrous metals the greatest number of inclusions was found in duralumin, aluminum-bronze and phosphor-bronze.

Duralumin (Fig. 12-1)

In the section parallel to the plane of rolling, hard copper aluminum particles are arranged in a dendritic pattern. It will be noted that in this section the grains are equiaxed, whereas in the side section the grains have an elongated form.

Aluminum-Bronze (Fig. 13)

In the top section the segregates of inclusions are in the form of wide bands; in the side section they show as thin streaks. The individual inclusions themselves were small and hard and apparently their shape had not been changed to any appreciable extent by the rolling.

Phosphor-Bronze (Fig. 14)

The fiber here was caused by the usual types of segregates of small inclusions and also by long intercrystalline threads or films apparently filled in by some readily soluble product. Such films are not infrequently found in phosphor-bronze with which difficulty is encountered in rolling.

Nickel-Silver

Fig. 12-2 shows what may be considered as a transition stage in the production of fiber. The nickel-silver apparently was not reduced very much in rolling and the dendritic structure is still in evidence. It can be seen, however, that in the side section the dendrites are more elongated than in the top section. In this material the dendritic pattern was not produced by the presence of a separate constituent or by an excessive number of inclusions, but by the variation in concentration of the same solid solution. In Fig. 12-3 the same material etched in a different manner shows

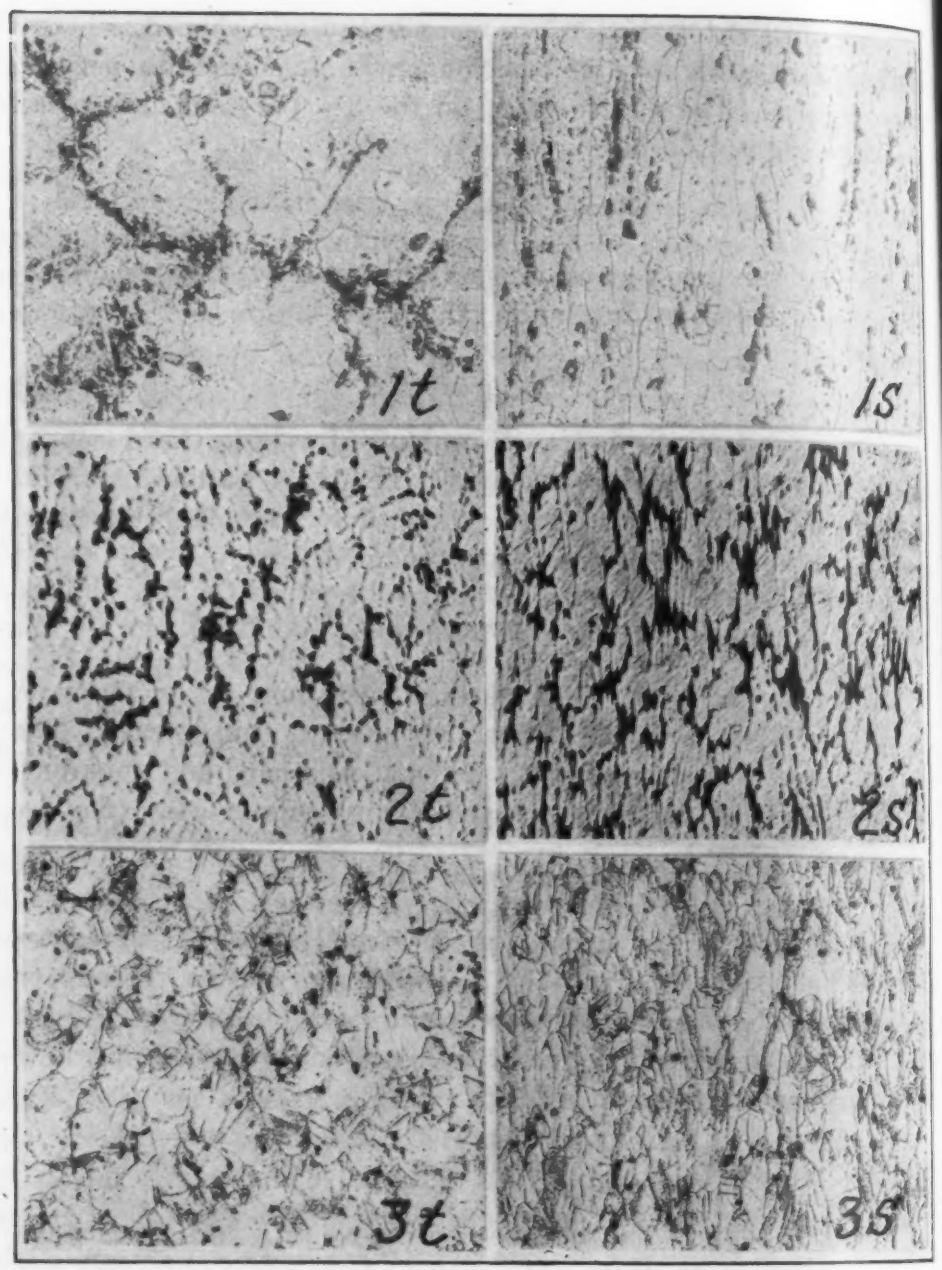

Fig. 12—Duralumin and Nickel Silver. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1. Duralumin B. 100X. Etched with 10 Per Cent Hydroxide Solution. In the Top Section the Dendritic Casting Pattern of the Hard Copper Aluminum Particles is Still in Evidence and the Grains are Equiaxed; in the Side Section the Particles are Arrayed Into Streaks and the Grains are Elongated. 2. Nickel Silver B. 50X. Etched with Ammonium Hydroxide and Hydrogen Peroxide. 3. Nickel Silver B. 100X. Etched with a Solution of 30 Parts Acetic Acid, 30 Parts Nitric Acid, 40 Parts Water. In the Side Section the Dendrites and the Grains are Elongated, While in the Top Section the Original Structure of the Cast State is More Nearly Preserved.

a uniform one-phase structure. This material did not show any marked difference in notched bar values to be attributed to "fiber."

Brass

Another cause which may contribute to the fibrous condition of a metal is the variation in composition due to segregation, which may be sufficiently great to cause the formation of another phase; although the alloy, according to its average chemical composition, would ordinarily consist of only one phase. This was noted in the case of the brass. Fig. 15-1 shows a layer in a side section of a brass specimen, in which some beta-brass may be detected. The greater part of the material, of course, is alpha-brass, which is softer than the beta-brass. The streak of the latter constituent together with the large number of inclusions surrounding it have introduced the element of fiber. It will be noted that the precipitation of the beta-brass in this spot and the presence of the large number of inclusions have materially diminished the grain size. Fig. 15-2 shows that the surrounding structure is much larger grained.

Discussion of Results

General Correlation Between the Impact and the Slow Bend Values

In Fig. 7 the metals are arranged in the order of the magnitude of their impact values and these are compared with the slow bend values and with the values for other properties of the materials.

It will be noticed that in most cases the slow bend values are lower than the impact values, equal or lower impact values occurring in the case of steel only. For all the other materials the slow bend and the impact curves follow each other (see Fig. 16), except for Monel metal B.

It will be noted that Monel metal B showed considerably higher resistance to impact than the Monel metal A.

All other properties of these two materials, including the slow bend values, were practically the same (the slow bend values for Monel metal B were even lower than those for Monel metal A). The micrographic examination of the two materials showed that the Monel metal A contained a much larger number of inclusions than the Monel metal B. Apparently, there is no well defined

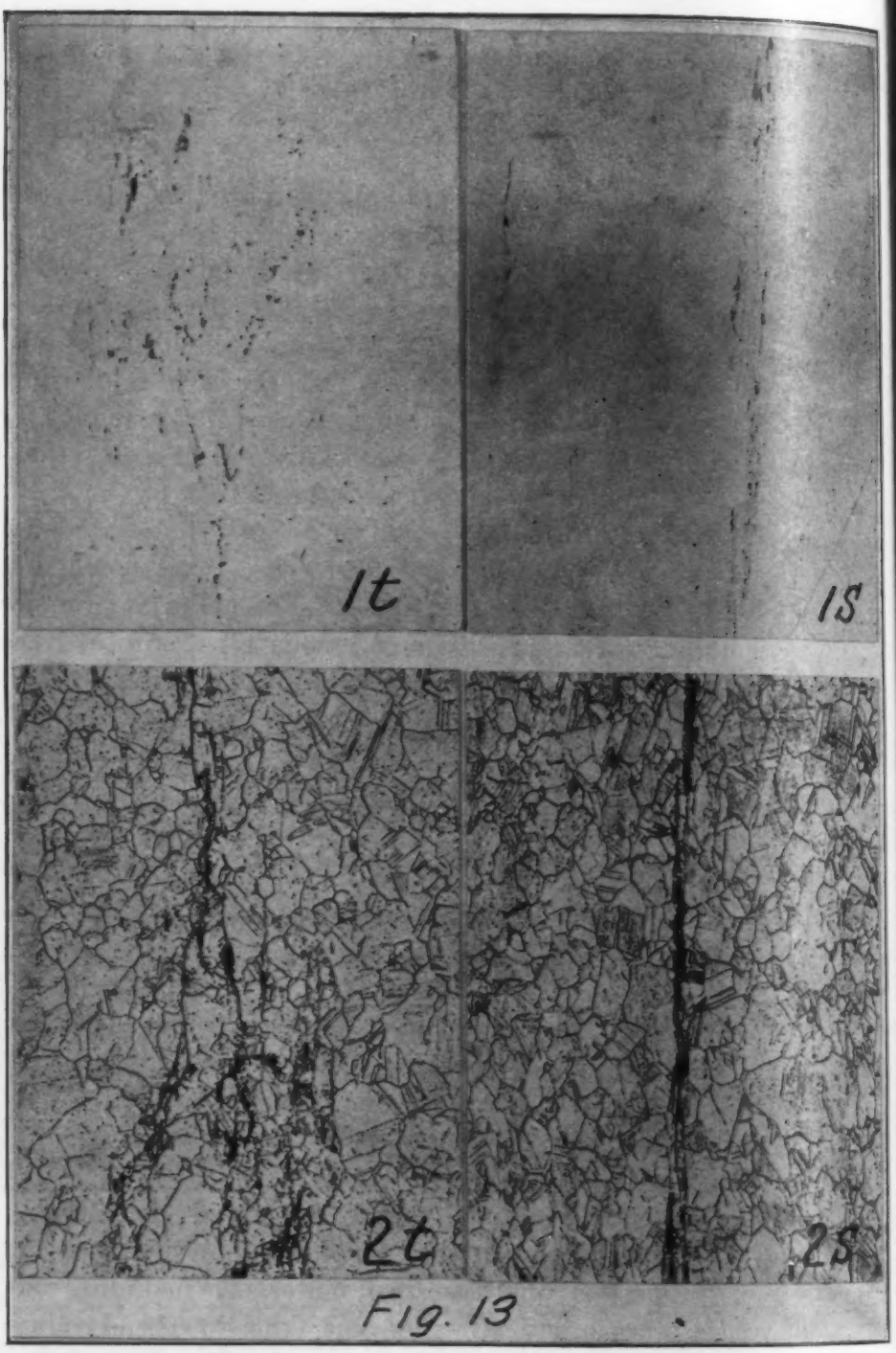

Fig. 13—Aluminum Bronze. 100X. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1. Not Etched. 2. Same Spots Etched with Ammonium Hydroxide and Hydrogen Peroxide. In the Top Section the Segregates of Inclusions Appear as Wide Streaks; in the Side Section as Narrow Threads. The Individual Inclusions Were Very Small and Hard and Were Apparently Not Changed by Rolling.

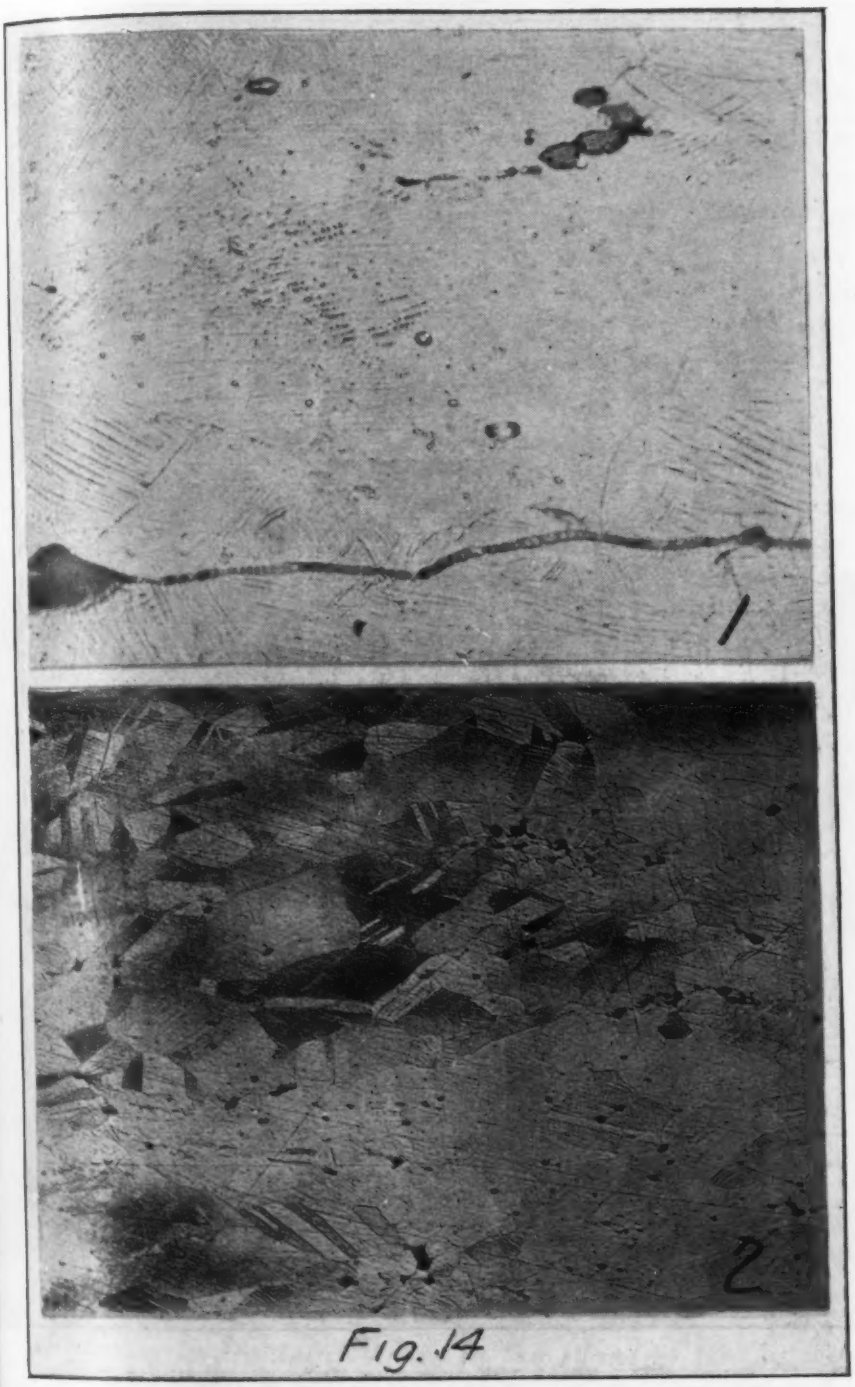

Fig. 14—Phosphor Bronze. Side Sections Etched with Ammonium Hydroxide and Hydrogen Peroxide. 1. Shows Two Types of Inclusions; Small Insoluble Blue Inclusions and Long Intercrystalline Threads Filled with a Brownish Readily Soluble Substance. 500X. 2. Shows "ghostlike" Appearance of Contaminated Area. The Dirty Portions Etch Lighter and Simulate the "ghost" Lines in Steel. 100X.

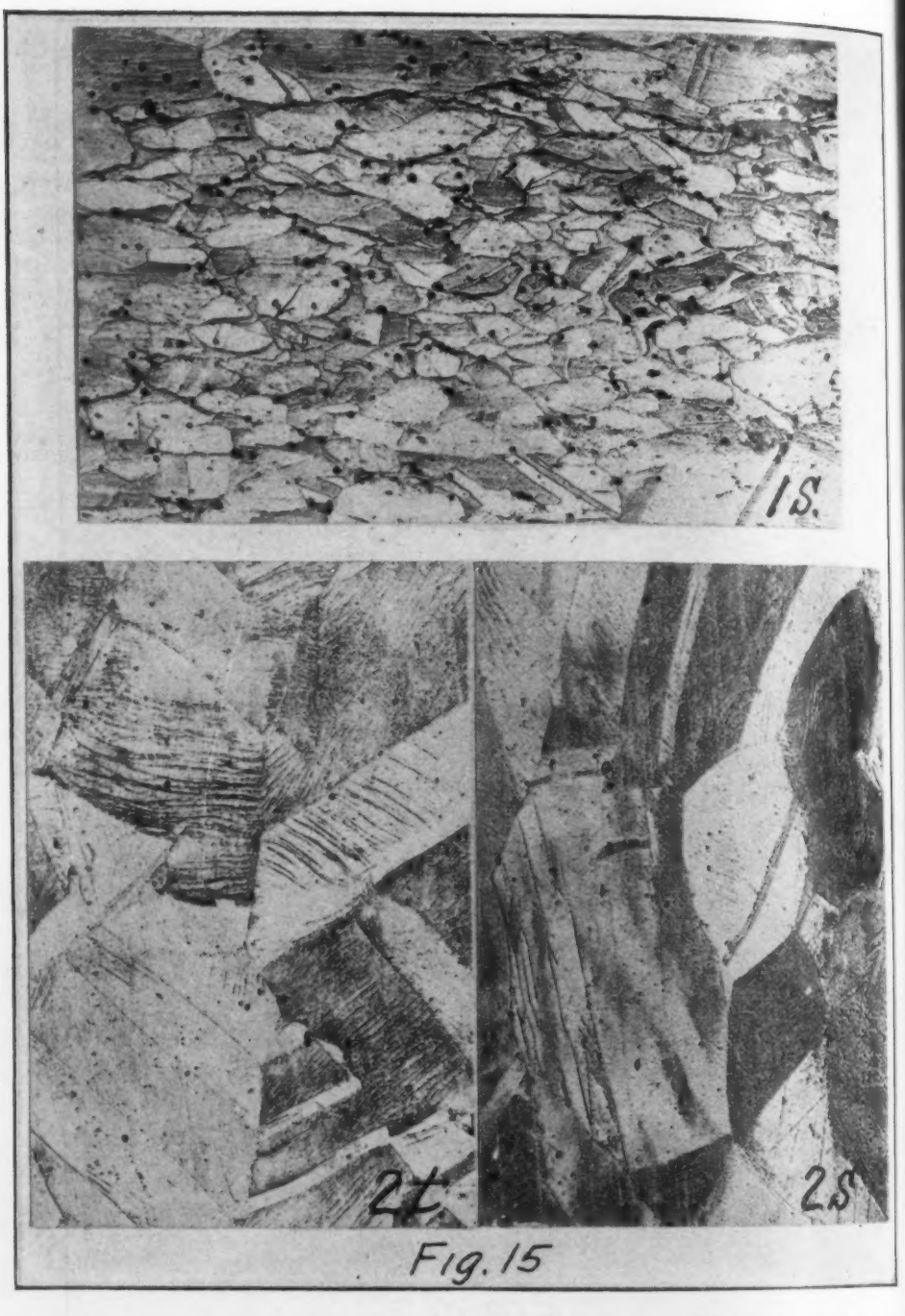

Fig. 15—Brass. 100X. Etched with Ammonium Hydroxide and Hydrogen Peroxide. "t" is the Notch in the Plane of Rolling. "s" is the Notch at Right Angle to the Plane of Rolling. 1. Shows Separation of Beta Phase in a Segregated Streak in Alpha Brass. The Beta Constituent is Indicated by the Arrows. The Inclusions are Very Numerous in This Streak and the Grain Size is Smaller. 2. Shows the Structure of the Material Outside the Streak.

relation between the notched bar values, whether obtained in an impact or in a slow bend test, and the tensile properties of these materials. Some values, however, which may be obtained in a slow bend test are quite definitely related to the values obtained in the tensile tests (Fig. 17). Thus, the maximum bending moment is approximately proportional to the tensile strength and the bending moment corresponding to the "proportional limit" of a slow bend diagram is approximately proportional to the tensile yield point.

The Variation Along the Length of a Bar of the Impact and of the Slow Bend Values

The materials used in this investigation were fairly uniform in their properties. In the case of the alloy tool steel, however, notched bar values varied quite considerably. This was shown (Fig. 18) by both impact and slow bend tests, the impact method being somewhat more sensitive. In these and other tests on more uniform materials, the average percentage deviation of individual values from the average value for a given material is about the same for impact and for slow bend. A smaller variation of results should not necessarily be considered an indication of greater accuracy for a given method of testing. Though this might be the case, it is, however, equally true that the uniformity of results may indicate that a given method does not show small differences in the resistance of the specimens. Thus, for Monel metal A (Fig. 19) the variation of the individual results for the impact test is much greater than for the slow bend test, but it is evident that this variation does not indicate the inaccuracy of the impact method because the latter was sufficiently accurate to show a decided difference between the specimens having notches differently placed in the bar. For this reason no use was made of the values of deviation of the individual results from the average.

The Difference in the Impact and the Slow Bend Values, Between the Specimens Having Notches in the Plane of Rolling and Those with the Notches at Right Angle to the Plane of Rolling

This difference is shown graphically in Fig. 20. In a specimen having the notch in the plane of rolling (value A_t) the

fracture developed at right angle to the direction of rolling and to the plane of rolling. In a specimen with the notch normal to the plane of rolling (value A_s), the fracture developed at right angle to the direction of rolling, but parallel to the plane

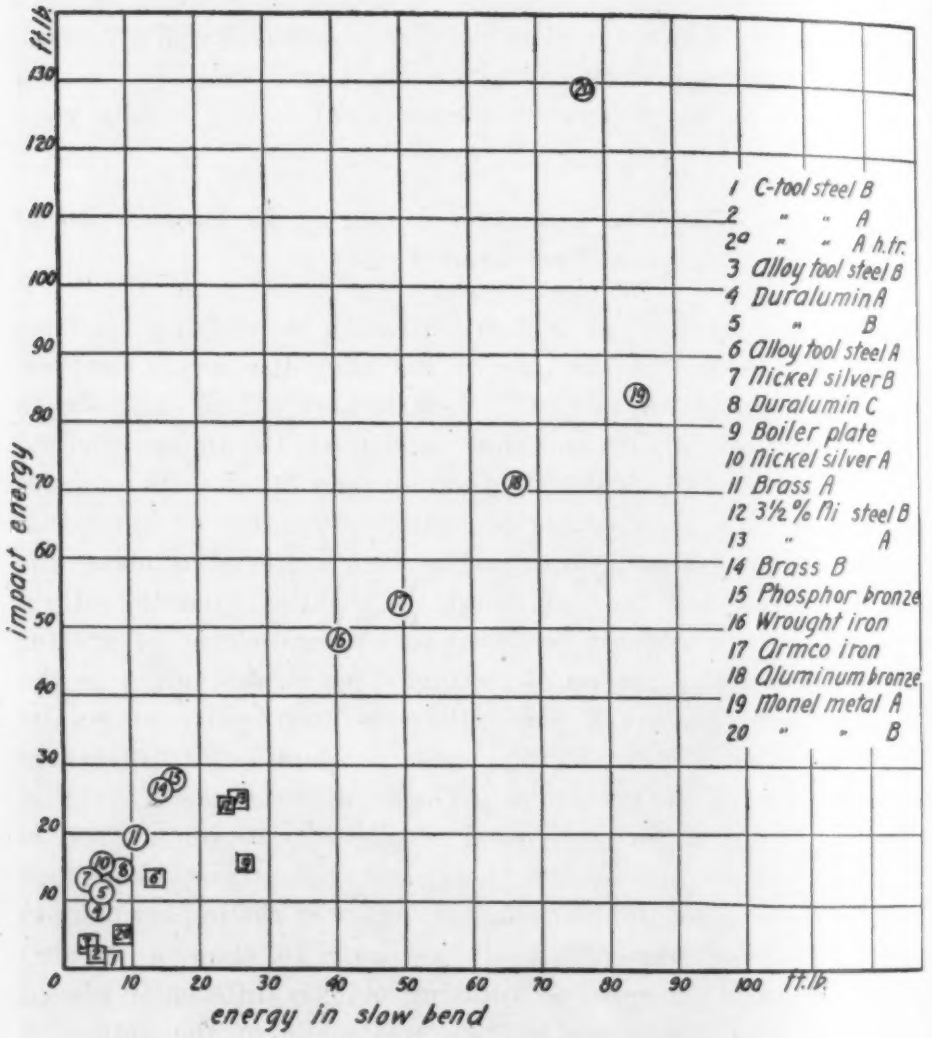

Fig. 16—Relation Between the Slow-Bend and the Impact Values.

of rolling. The average ratios A_t/A_s for all tested materials are given in Table IV.

The values given in Table IV show that the impact method is more responsive than the slow bend method to the variation in the position of the notch in relation to the rolled surface. Incidentally, this table indicates also that the "sharp" notch is the most sensitive of those used.

The metallographic examination has shown that a large difference in the notched bar values, for the specimens with the notch on the top (in the plane of rolling) and those with the notch on the side (at right angle to the plane of rolling) is associated with fibrous or lamellar structure of a material. In a specimen of

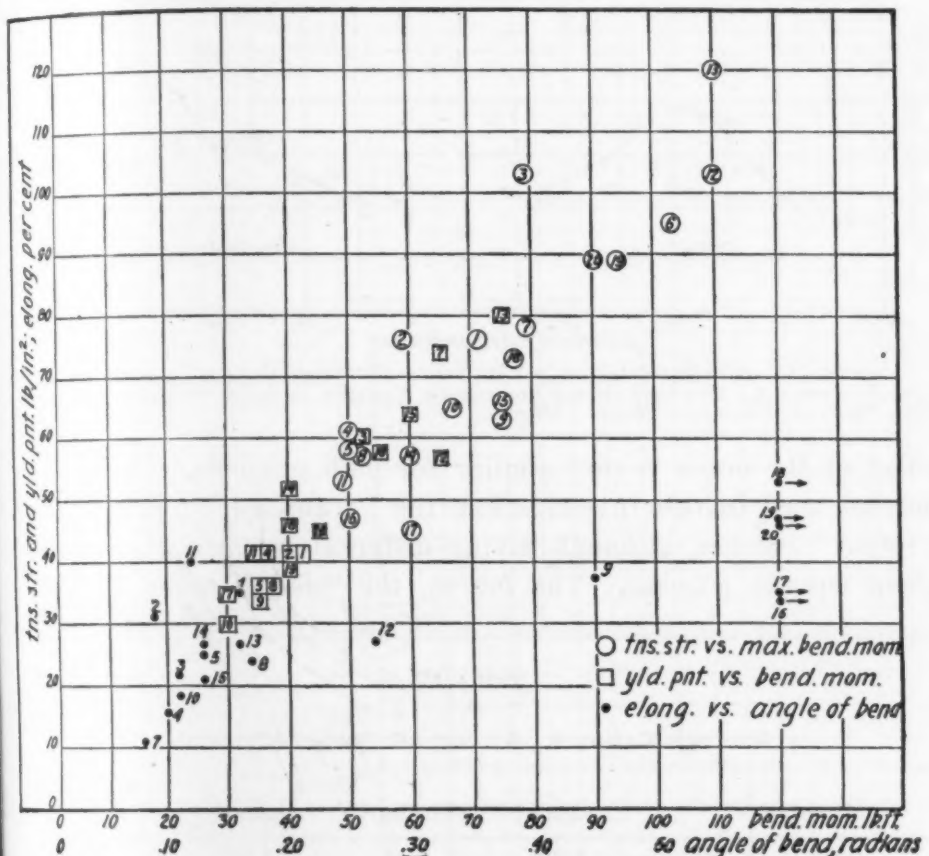
tns. str. and yld. pnt. lb./in.²; elong. per cent
bend. mom. lb.ft.
angle of bend, radians
tns. str. vs. max. bend. mom.
yld. pnt. vs. bend. mom.
elong. vs. angle of bend

Fig. 17—Relation Between Some of the Slow-Bend Values and the Values for the Tensile Properties of the Materials. The Numbers Indicate the Materials as Given in Fig. 7. The Yield Point is Plotted Against the Bending Moment Corresponding to the Portion of the Diagram Near B. (See Fig. 4.) The Angle of Bend is That at Which the Bending Moment Begins to Decrease Rapidly or at Which the Resistance of a Specimen Drops Suddenly to Zero.

homogeneous material the fracture extends across the specimen and, once started, its acts itself as a notch. It may happen, however, that before the fracture has penetrated into the inclusion a shear failure occurred in the plane of the inclusion, leaving the unbroken portion of the specimen unnotched. A greater resistance, therefore, may be expected for a specimen with the notch parallel to the plane of the inclusion, than with the notch at right angle to it.

The Relative Efficiency of the Different Notches in Detecting Differences in the Notched Bar Resistance of the Materials

In Fig. 21 are shown the impact and in Fig. 22 the slow bend values for each of the four notches used in series 2. The

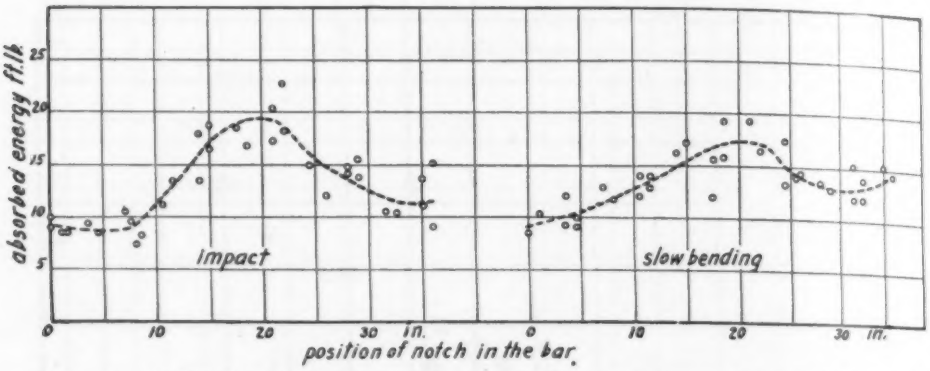

Fig. 18—Variation of the Impact and the Slow-Bend Values Along the Length of a Bar of Alloy Tool Steel A. This Steel Showed Considerable Variation of the Notch Bar Properties, the Other Materials Being More Nearly Uniform.

effect of the notch is very similar for both methods. Of the four notches used in this investigation, the "standard," "sharp," and "round" notches, although giving different numerical values, are about equally efficient. The fourth, the "deep" notch, is appar-

Table IV

Average Ratios A_t/A_s for All Tested Materials

Machine	Notch "sharp"	"standard"	"round"	"deep"
Impact	1.20	1.16	1.08	1.05
Slow bend	1.15	1.08	1.04	1.05

ently less efficient than the others; showing less differences in the notched bar properties of materials. For brittle materials it gives larger values than the "standard" and "sharp" notches and for tough materials smaller values.

The Effect of Varying the Radius of the Notch on the Energy

In this series of tests the net thickness of specimen was in all cases 8 millimeters (0.315 inch) and the radius of notch was 0; 0.25 millimeters (0.01 inch) and 1 millimeter (0.0394 inch).

The effect of the radius of the notch is shown in Fig. 23.

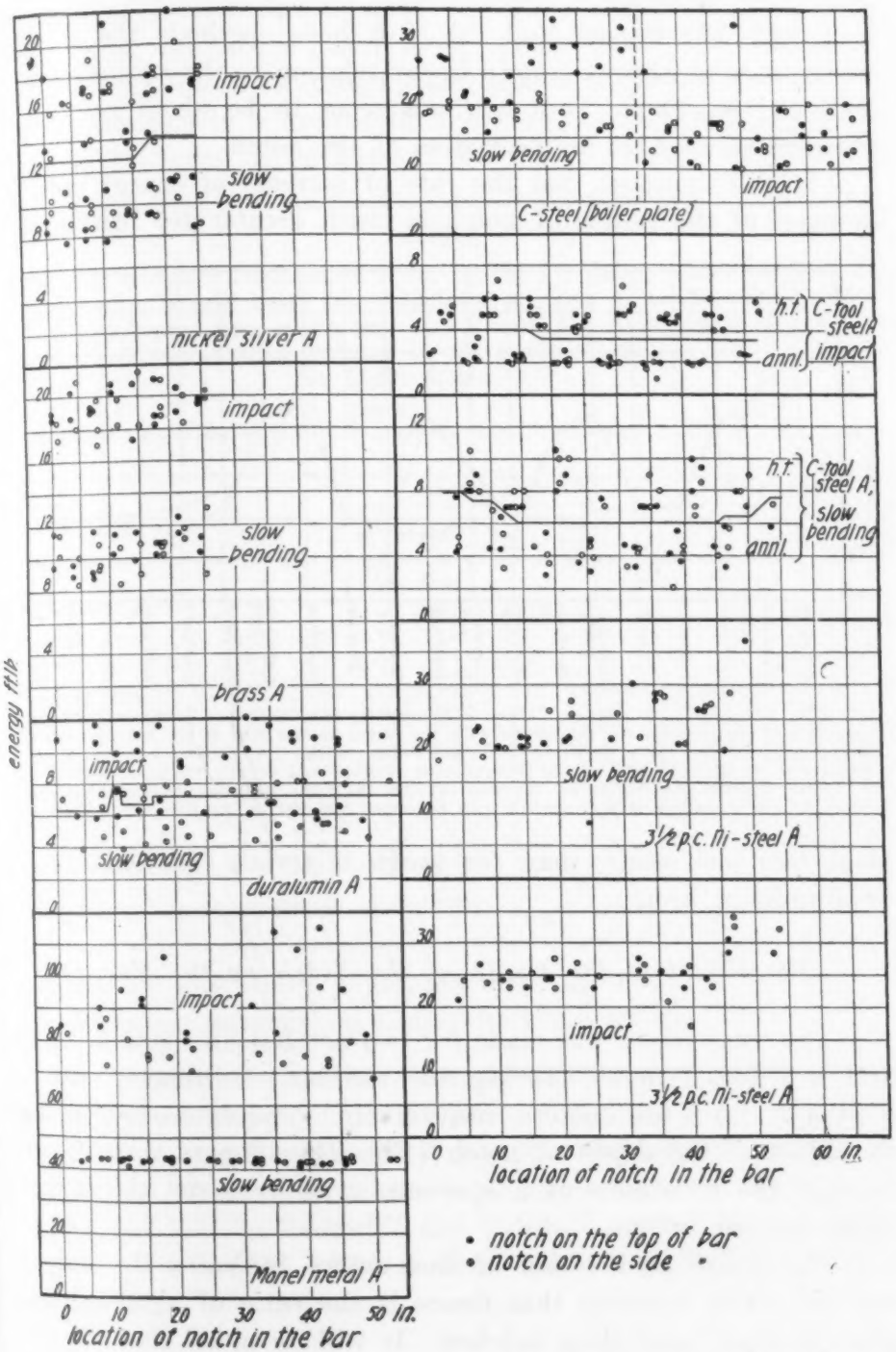

Fig. 19—Variation of the Impact and the Slow-Bend Values Along a Bar in Series 1 Tests (Slow-Bend Values for Monel Metal are Not Reduced to the Same Angle of Bend as in Impact Machine).

For both, the impact and the slow bend methods the absorbed energy has an approximately linear relation to the radius of notch and, on the whole, both methods seem to be about equally responsive to changes in the radius of the notch.

It will be noted that the rate of increase of energy with the increase of the radius of notch is much greater for brittle mate-

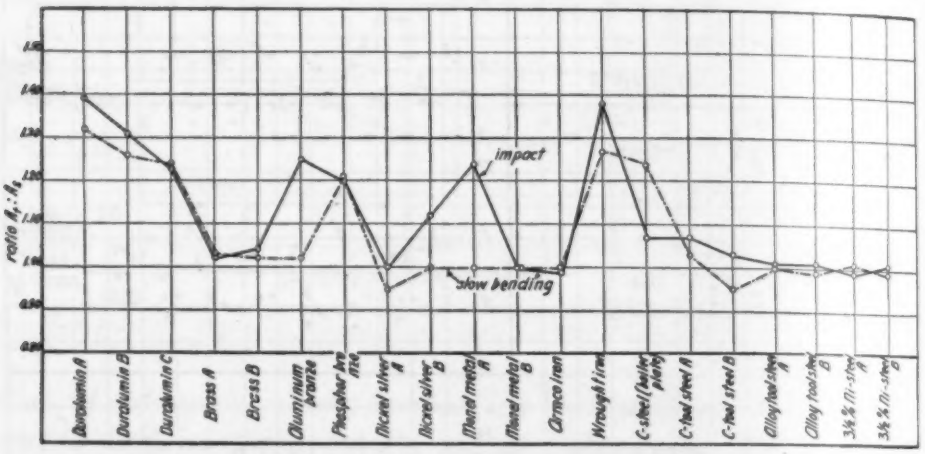

Fig. 20—Ratios of Average Values of Energy for the "Standard," "Sharp," "Round," and "Deep" Notches for the Specimens with the Notch on the Top of the Bar and with the Notch on Its Side. In a Specimen with the Notch on the Top (Value A_t), the Fracture Developed at Right Angle to the Direction of Rolling and to the Plane of Rolling. In a Specimen with the Notch on the Side (Value A_s) the Fracture Developed at Right Angle to the Direction of Rolling But in a Direction Parallel to the Plane of Rolling.

rials, like tool steels, than for tough materials like Monel metal or aluminum bronze.

The Effect of the Depth of the Notch on the Energy

The comparison was made for two notches: a "round" notch, and a "deep" notch, having the radius 1 millimeter and the depths 2 and 5 millimeters, respectively. The curves which show the effect of the depth of notch (Fig. 24) all pass through zero, because the resistance of a specimen with zero net thickness, is equal to zero.

The figure at the end of each curve indicates the material and the value opposite that figure is the ratio of absorbed energies for round and deep notches. It will be noted that the ratio decreases with the decrease of absorbed energy for both methods, that is, the effect of the depth of notch is greater for tough materials and is quite small for brittle materials.

The results shown in Fig. 25 seem to be scattered and no

attempt has been made to draw a curve. However, it will be noticed that the above ratio never exceeded 2.5 and seems to approach this value for tough materials. On the other hand, for brittle materials it is approaching unity. In all probability, the curve of averages, if such could be drawn, would start at the ordinate 1.0 and would asymptotically approach the ordinate 2.5. The following interpretation may be given to Fig. 25:

Table V

Coefficients α and β Determined from Values for Sharp and Deep Notches Obtained in Impact Tests and Calculated $A_{s,t}$ and A_r as Compared with Experimental Impact Values. All Values are Averages of Those Obtained with Notches in the Plane of Rolling and at Right Angle to It

$A = A_1 + A_2 = \alpha\, br\sqrt{h} + \beta bh^2$, where b, r and h are in mm.

Material	α	β	Standard notch				Round notch			
			A_1= 7.05 alpha	A_2= 640 beta	Calculated $A=A_1+A_2$	Experimental val. of A	A_1= 28.2 alpha	A_2= 640 beta	Calculated $A=A_1+A_2$	Experimental val. of A
			ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.
Duralumin B.	.154	.0169	1.09	10.81	11.90	11.41	4.34	10.81	15.15	14.68
Duralumin C.	.211	.0205	1.49	13.13	14.62	14.66	5.95	13.13	19.08	18.96
Brass B.	.448	.0389	3.16	24.88	28.04	26.26	12.64	24.88	37.52	33.47
Aluminum bronze	.476	.1084	3.35	69.35	72.70	71.33	13.42	69.35	82.77	79.40
Phosphor bronze	.418	.0419	2.95	26.82	29.77	27.76	11.80	26.82	38.62	36.65
Nickel silver B.	.324	.0195	2.29	12.48	14.77	13.81	9.14	12.48	21.62	17.59
Monel metal B.	.184	.1996	1.30	127.7	129.0	129.0	5.19	127.7	132.89	130.50
Armco iron	.335	.0809	2.36	51.75	54.11	53.79	9.45	51.75	61.20	62.81
Wrought iron	.249	.0706	1.76	45.15	46.91	48.89	7.02	45.15	52.17	52.51
C-tool steel B.	.245	.0016	1.73	1.02	2.75	1.60	6.92	1.02	7.94	6.84
Alloy tool steel B.	.293	.0039	2.07	2.49	4.56	3.70	8.26	2.49	10.75	8.71
3½% nickel steel B.	.777	.0290	5.48	18.54	24.02	25.12	21.94	18.54	40.48	37.67
Average					36.0	35.6			43.4	41.7
Avg. deviation from the average of experimental values					2.9%				4.8%	

1. For brittle materials the absorbed energy is nearly independent of the depth of notch (ratio of A_r/A_d approaches 1.0).

2. For tough materials it is approximately proportional to the square of the net thickness of specimen (the ratio of net thicknesses for the "round" and "deep" notches is 1.6 and the square of 1.6 is 2.56). This is discussed at a greater length in the next section.

Empirical Formula for Absorbed Energy

On the basis of the experimental data stated in the preceding paragraphs, it may be assumed that if the energy can be ex-

pressed as a function of the geometrical characteristics of the specimen, it should consist of at least two terms, one of which contains as a multiplication factor the first power of the radius of

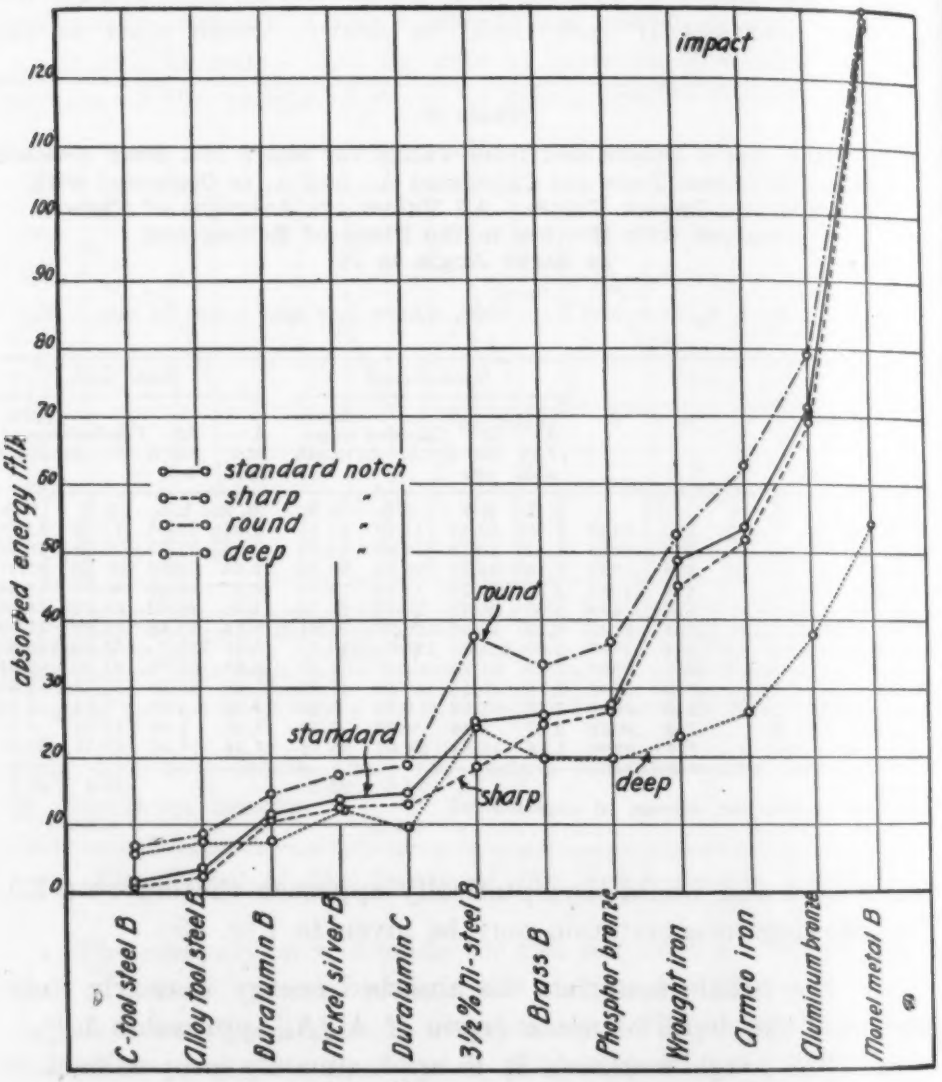

Fig. 21—Effect of Notch on the Impact Values.

notch (r) and the other, the square of the net thickness of the specimen (h).

Evidently, both terms should disappear when h = 0. The simplest form of a function, which satisfies these partially empirical and partially theoretical requirements, is this:

$$A = a\,brh^x + \beta bh^2 \qquad (1)$$

where a and β are numerical coefficients constant for a given

material, and b is the width of the specimen, it being assumed that the energy is proportional to the width of the specimen.

As all values obtained from tests of materials are only ap-

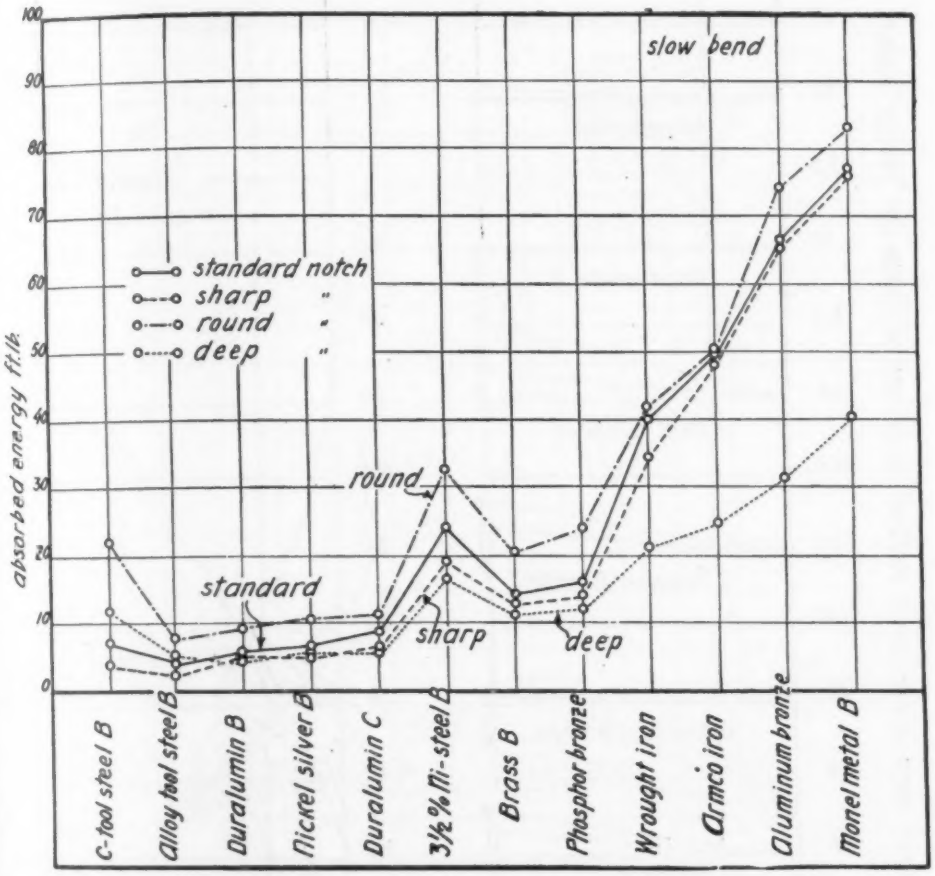

Fig. 22—Effect of Notch on the Slow-Bend Values.

proximations, the direct determination of x is impracticable. By several trials it was found that the value $x = \frac{1}{2}$ fits the formula with a sufficient degree of accuracy.

We have then: $$A = \alpha br\sqrt{h} + \beta bh^2 \qquad (2)$$

In order to determine α and β it is necessary to know the energy for two different notches. In this work α and β were determined, using values for "sharp" and "deep" notches. In Tables V and VI are found these values of α and β, and the calculated value of A for "standard" and for "round" notches.

In Fig. 26 the ratios of α/β were plotted against the experimental values of the energy for the "standard" notch. It is evident that for extreme values of the energy the above ratio follows

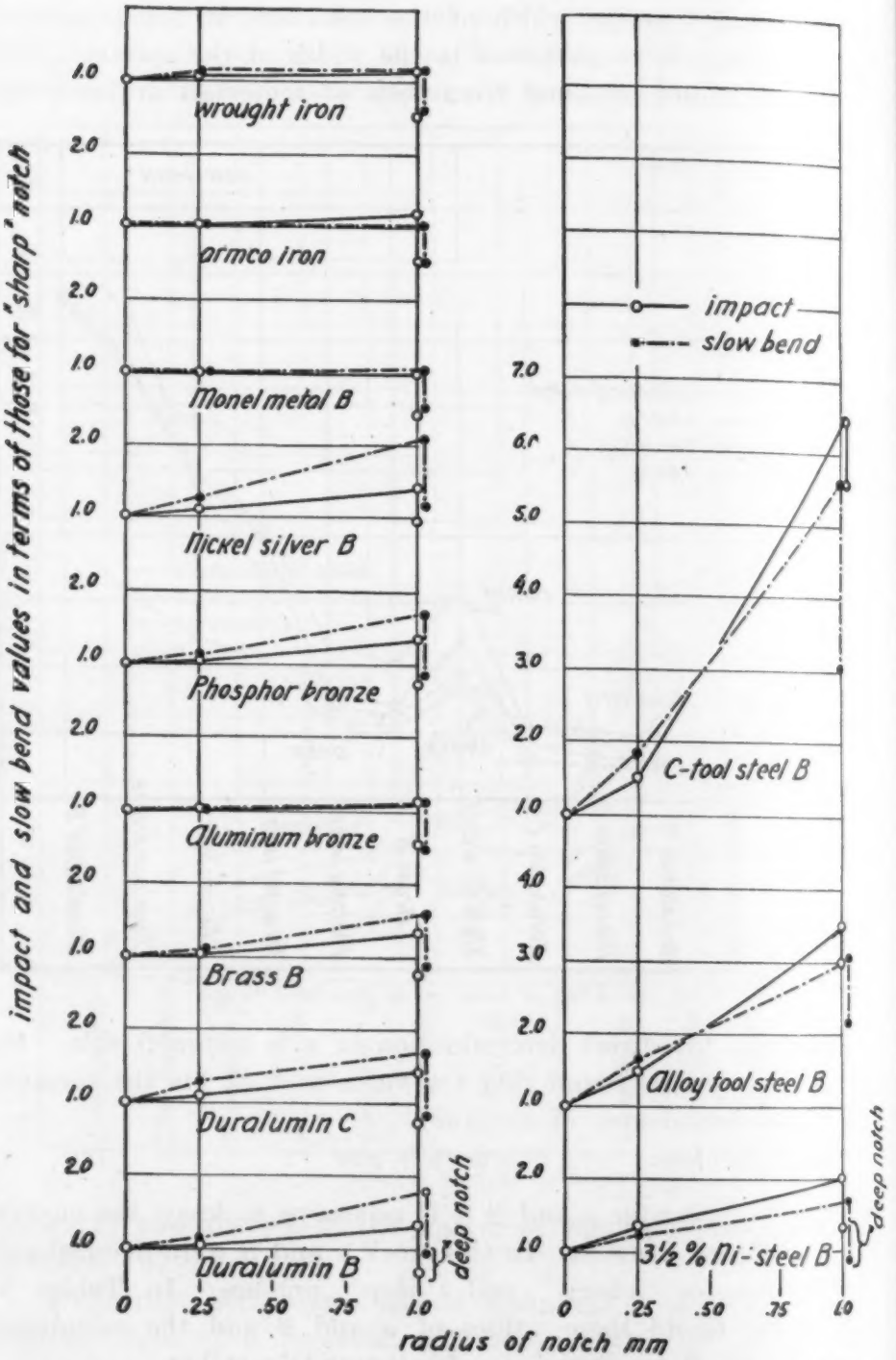

Fig. 23—Effect of the Radius of Notch on the Impact and on the Slow-Bend Values. All Values are Given in Terms of Those for the "Sharp" Notch. The Values for "Deep" Notch Should Not be Compared Directly with the Other Values, as the "Deep" Notch Differed from Them in Depth.

a quite definite curve. However, for materials of medium toughness the individual values of a/β are scattered. An approximate relation between the ratio a/β and the energy may be expressed

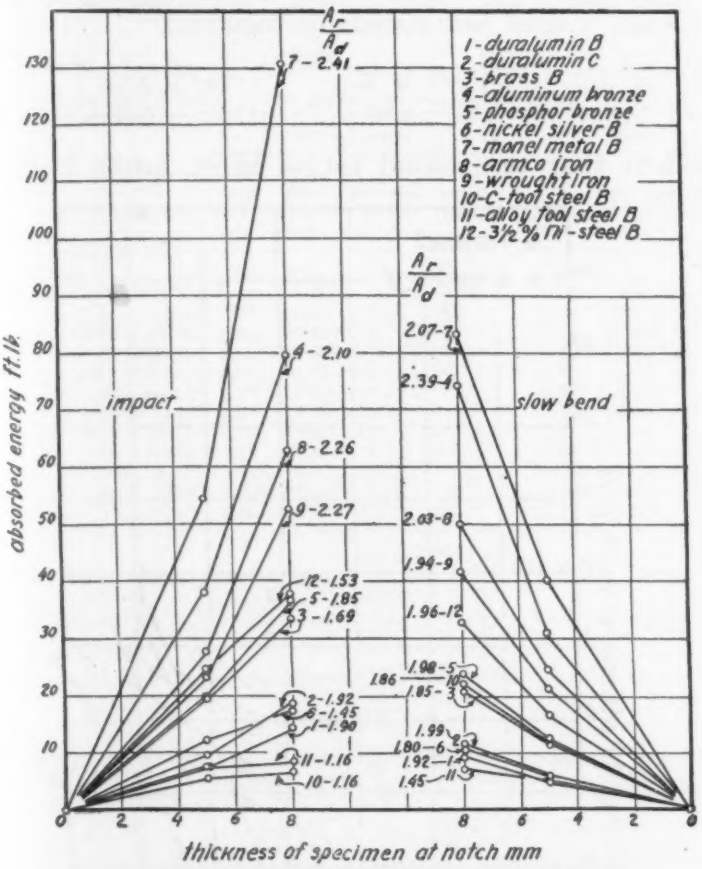

Fig. 24—Effect of the Depth of Notch on the Impact and on the Slow-Bend Values. The Radius of the Notch was in All Cases 1 Millimeter (0.0394 Inch). The Figures at the Ends of the Curves Indicate the Materials, and the Values Opposite These Figures are the Ratios of the Energies for the "Round" and "Deep" Notches.

by a number of functions, one of the simplest being $a/\beta = \frac{250}{A_{st}}$, where A_{st} is the experimental value of the energy for the "standard" notch. Assuming this relation, the energy for any notch may be expressed directly in the terms of that for the "standard" notch. After the necessary transformations we have:

$$A = A_1 + A_2 = \frac{br\sqrt{h} \times A_{st}}{7.05 + 2.56\ A_{st}} + \frac{bh^2A^2_{st}}{1765 + 640\ A_{st}} \qquad (3)$$

In Table VII are found the values of A for the deep and round notch, which were computed according to the formula—(3).

Comparing the calculated values of the impact energy for the "round" notch obtained by means of coefficients α and β,

$$A = \alpha br\sqrt{h} + \beta bh^2$$

and the same values calculated by formula

$$A = \frac{br\sqrt{h} \times A_{st}}{7.05 + 2.56\ A_{st}} + \frac{bh^2 \times A^2_{st}}{1765 + 640\ A_{st}}$$

it is evident that the second terms agree fairly well. The first

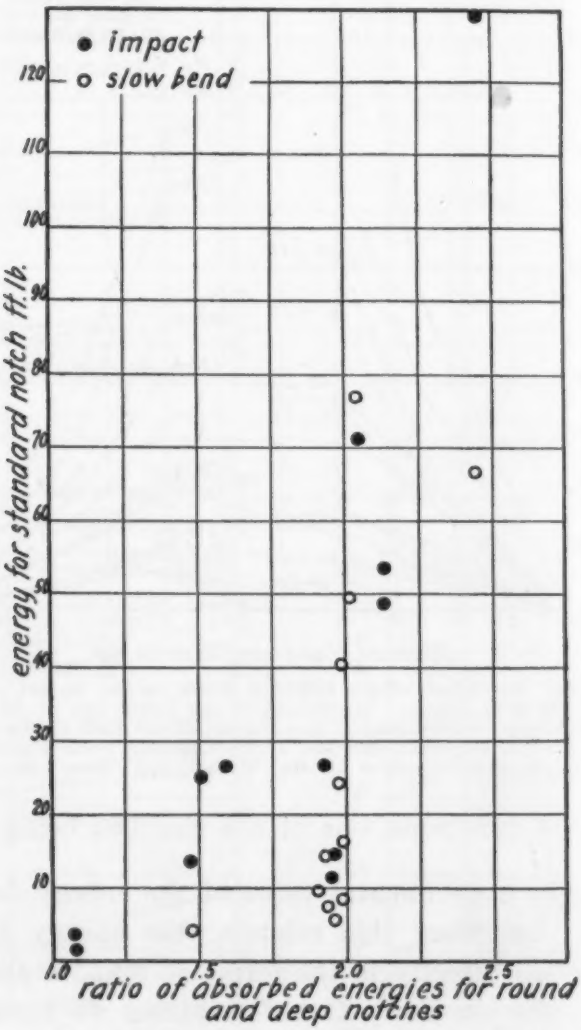

Fig. 25—Increase of the Effect of the Depth of Notch with the Increase of Absorbed Energy.

terms show greater discrepancies which make the determination of A, from its value for one notch only, less reliable than from the values for two different notches.

Table VI

Coefficients α and β Determined from Values for Sharp and Deep Notches Obtained in Slow Bend Tests and Calculated A_{st} and A_r as Compared with Experimental Slow Bend Values. All Values are Averages of A_t and A_s

$A = A_1 + A_2 = \alpha\, br\sqrt{h} + \beta bh^2$, where b, r and h are in mm.

Material	α	β	Standard notch				Round notch			
			A_1 = 7.05 alpha	A_2 = 640 beta	Calculated $A = A_1 + A_2$	Experimental val. of A	A_1 = 28.2 alpha	A_2 = 640 beta	Calculated $A = A_1 + A_2$	Experimental val. of A
			ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.
Duralumin B.	.124	.0079	0.87	5.06	5.93	5.81	3.50	5.06	8.56	9.18
Duralumin C.	.139	.0104	.98	6.66	7.64	8.84	3.92	6.66	10.58	11.37
Brass B.	.277	.0200	1.95	12.80	14.75	14.05	7.81	12.80	20.61	20.74
Aluminum bronze	.242	.1025	1.71	65.60	67.31	66.80	6.82	65.60	72.42	74.50
Phosphor bronze	.300	.0219	2.11	14.01	16.12	16.05	8.46	14.01	22.47	24.17
Nickel silver B.	.176	.0077	1.24	4.93	6.17	6.42	4.97	4.93	9.90	10.56
Monel metal B.	.465	.1187	3.28	75.90	79.18	76.8	13.12	75.90	89.02	83.20
Armco iron	.270	.0750	1.90	48.00	49.90	49.80	7.62	48.00	55.62	50.30
Wrought iron	.350	.0538	2.47	34.40	36.87	40.10	9.87	34.40	44.27	41.90
C-tool steel B.	.464	.0062	3.27	3.97	7.24	7.27	13.10	3.97	17.07	22.24
Alloy tool steel B.	.194	.0039	1.37	2.49	3.86	4.17	5.47	2.49	7.96	7.71
3½% nickel steel B.	.412	.0300	2.91	19.20	22.11	24.29	11.62	19.20	30.82	31.00
Average					26.4	26.7			32.4	32.3
Avg. deviation from the average of experimental values					3.4%				6.5%	

Table VII

Values of Energy for Deep and Round Notches in Impact Test, Calculated from Those for Standard Notch, According to Formula

$$A = A_1 + A_2 = \frac{br\sqrt{h} \times A_{st}}{7.05 + 2.56A_{st}} + \frac{bh^2 \times A_{st}^2}{1765 + 640A_{st}}$$

Material	Round notch				deep notch			
	A_1	A_2	Calculated $A = A_1 + A_2$	Experimental val. of A	A_1	A_2	Calculated $A = A_1 + A_2$	Experimental val. of A
	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.
Duralumin B.	8.88	9.18	18.06	14.68	7.00	3.59	10.59	7.71
Duralumin C.	9.28	12.34	21.62	18.96	7.30	4.92	12.22	9.87
Brass B.	10.00	23.86	33.86	33.47	7.88	9.28	17.16	19.81
Aluminum bronze	10.62	68.70	79.32	79.40	8.37	27.32	35.69	37.84
Phosphor bronze	10.04	25.28	35.32	36.65	7.90	9.85	17.75	19.86
Nickel silver B.	9.19	11.54	20.73	17.59	7.82	4.50	12.32	12.16
Monel metal B.	10.80	126.40	137.20	130.50	8.50	40.80	49.30	54.07
Armco iron	10.50	51.20	61.70	62.81	8.27	19.95	28.22	27.77
Wrought iron	10.45	46.20	56.65	52.51	8.23	18.08	26.31	23.74
C-tool steel B.	9.40	.59	9.99	6.84	3.19	.23	3.42	5.88
Alloy tool steel B.	6.32	2.12	8.44	8.71	4.98	.63	5.61	7.51
3½% nickel steel B.	9.92	22.65	32.57	37.67	7.83	8.77	16.60	24.64
Average			43.0	41.7			19.6	20.9
Average deviation from the average of experimental values			6.3%				13.0%	

Conclusions

Machine

1. A notched bar test in the slow bend machine requires more care from the operator than an impact test, and the machine itself is more likely to get out of order than an impact machine.

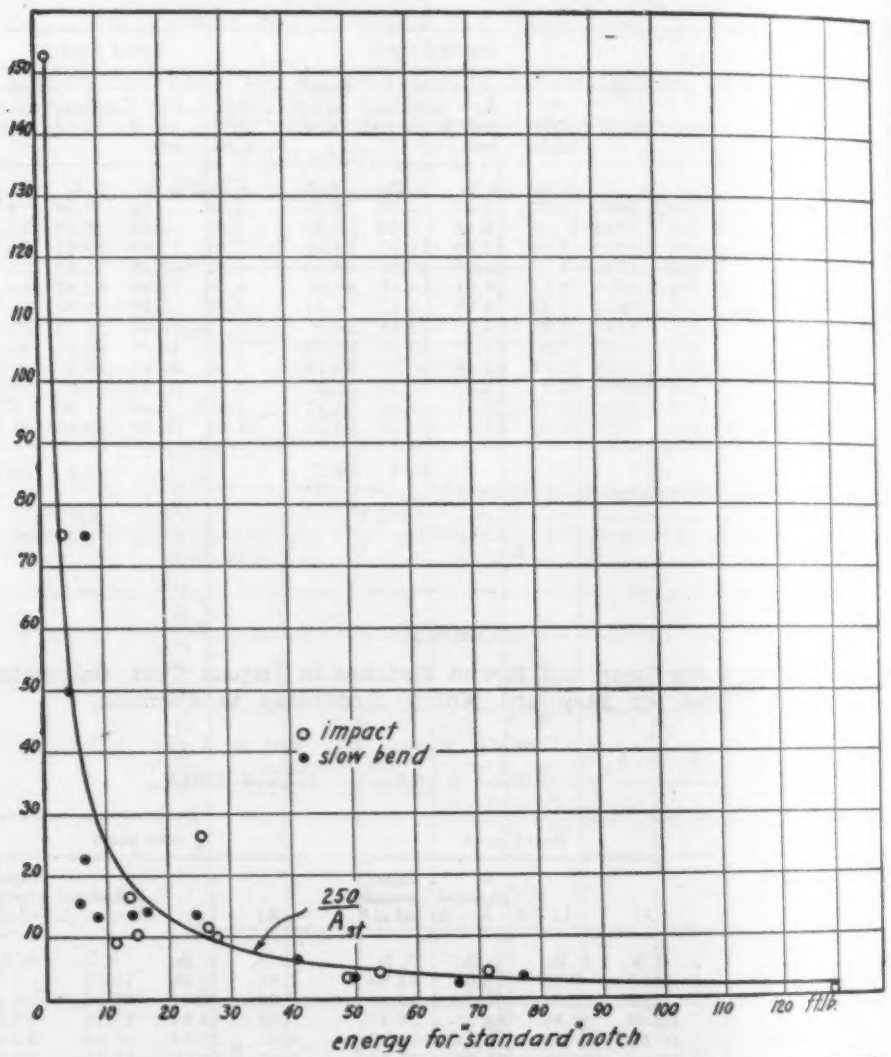

Fig. 26—Relation Between the Coefficients Alpha and Beta in the Formula $A = abr\sqrt{h} \times \beta h^2$.

2. The slow bend values for specimens of tough materials which do not break entirely, are not directly comparable with the impact values, because the angle of bend is different for the two machines.

Although the reduction of the slow bend values to the same

angle of bend is only approximate, in most cases the approximation is sufficiently accurate for practical purposes.

3. The slow bend values have a number of errors, some of which, at least, should be corrected, the corrections being of an approximate nature. The sum of all the errors in a slow bend is, however, of about the same magnitude as in an impact machine.

4. In addition to a value of absorbed energy, the slow bend test gives other information regarding the manner in which the energy is absorbed, which is not easily obtainable in an impact test; such, for instance, as the bending moment corresponding to any angle of bend.

Effect of Speed

5. Usually, the slow bend method gives lower values for the non-ferrous materials and higher values for steels than does the impact method. The slow bend shows less difference between the tough and brittle materials than does the impact method.

6. The slow bend and the impact values for non-ferrous materials are fairly comparable among themselves. This relation is not as close for the ferrous materials.

7. There is no well defined relation between the impact or the slow bend values and the other properties of materials. Some values, however, which are obtained in a slow bend test are correlated with the tensile test values. Thus, the bending moment given by a slow bend diagram is in close relationship to the tensile strength and to the yield point for practically all tested materials.

8. Both methods are about equally reliable in detecting the differences in the notched bar values which may be present for the specimens cut from the same bar, or for the specimens having the notches differently placed in respect to the rolling direction.

Fracture of Specimen

9. The notch bar test and, particularly, the notched bar impact test is sensitive in showing up the directional differences in the properties of rolled metals caused by their fibrous structure, and may be more conveniently used for this purpose than other tests. This refers to the specimens cut in the direction of rolling as all the materials used in this investigation were in the shape of flat bars.

10. When the notched bar values are given in a specification or otherwise, mention should be made of the location of the notch relative to the plane of rolling and to the rolling direction.

11. The variation in the individual values of notched bar tests made on the same sample and under identical conditions can, in a good many cases, be directly accounted for by the structural condition of the metal instead of being considered as test errors which are beyond the control of the operator.

12. It is evident that the notched bar impact test may be used as a convenient method to measure the weakening effect of inclusions, where other tests would be more costly or less conclusive.

13. The metals here tested were comparatively "clean" and no general conclusions are being made in respect to the "dirtiness" of metals and its effect on toughness. This question, however, seems to deserve further study with the purpose of using the impact test as a sensitive method of detecting "dirty" metals.

Notch

14. For both the slow bend and for the impact test the energy increases linearly with the increase of the radius of notch, if the depth of the notch is constant.

15. For both the slow bend and for the impact tests on tough materials, the energy increases rapidly with the increase of the net thickness of the specimen. For brittle materials the effect of the net thickness is comparatively small.

16. The "sharp," "standard" and "round" notches place materials in the same relative order for their resistance to impact or to slow bend. For brittle materials the "sharp" and the "standard" notches are preferable because the notched bar values for such materials are more responsive to the effect of the radius of the notch.

17. The "deep" notch is not as good as the other three notches which were used in this work.

The smaller net thickness of the specimen having this notch is responsible for the lower values for tough materials, which are greatly affected by the net thickness, while the values for the specimens from brittle materials are comparatively little affected by the net thickness. On the other hand, the absence of a sharp

angle at the bottom of this notch tends to give comparatively high values for brittle materials, thus making the extreme differences less pronounced.

Empirical Formula

18. The energy absorbed in an impact or in a slow bend test may be expressed by the equation

$$A = a\,br\sqrt{h} + \beta bh^2$$

in which a and β are constants for a given material; b, r and h are the width of specimen, the radius of notch, and the net thickness, of specimen, respectively. Constants a and β may be found by determining energy for two different notches.

Bibliography

A list of works on impact testing will be found in *Proceedings*, American Society for Testing Materials part II; 1922; p. 9. It gives, also, a chronological and a subject index. In addition to this, a list of works which were published in 1922 and later is given below.

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RETAINED AUSTENITE—A CONTRIBUTION TO THE METALLURGY OF MAGNETISM

By J. A. Mathews

Abstract

In this paper the author discusses the development of permanent magnet steels, methods of hardening them and methods of testing them.

He points out three main factors: First, that in all normally hardened medium or high carbon steels and the usual engineering alloy steels, austenite is always present with martensite. Second, that in a wide variety of alloy steels, notably those capable of hardening readily in oil, there is more austenite present after oil quenching than after water quenching for normal hardening. Third, that austenite is a cause of increased magnetic permanence or retentivity in those alloys capable of hardening readily in oil.

IT seems to be the prevailing belief that upon quenching ordinary carbon or alloy steel from a bright red heat into water, the transformation of austenite to martensite is complete. A moment's thought should suffice to convince one that these conditions are not the ones from which one may expect equilibrium. The change from gamma iron to alpha iron is but partial in most cases, yet it is only recently that this fact has been emphasized by the work of several investigators. The extent to which these mixtures of alpha and gamma iron affect the properties of various steels remains to be studied.

The experiments upon which this paper is based cover the period of my connection with the steel industry. Many of them were conducted by the writer personally and many of them by his former and present associates at the Halcomb Research Laboratories, under his direction. In order to present the subject clearly it is necessary to review some of this earlier work. The fascinating subject of magnetism has occupied my attention for many years. In fact, the investigation of permanent magnet steels was the first task assigned me when I went to the Sanderson Works in 1902. It was early recognized that every change

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in the physical state of iron or steel is accompanied by a corresponding change in the magnetic properties, and it was an early dream of mine to learn how to coordinate the mechanical and magnetic properties. It is still a dream. In 1904, following my suggestion, two students in a western institution conducted an investigation of the magnetic and mechanical properties of a series of plain carbon steels. This, I believe, was long before the term "magnetic analysis" had crept into our literature. About 1910 we completed a magnetic study of four types of high speed steel as hardened and tempered in many ways. The results of both investigations were disappointing and were never made public.

In 1912 the late Prof. Henry M. Howe, in his presidential address to the International Congress for Testing Materials in New York, called attention to the desirability of developing various forms of non-destructive tests which would test the object itself and not samples supposed to more or less nearly represent the object. This gave a new impetus to the matter of magnetic tests for purposes other than merely to determine the magnetic properties themselves. The late Dr. Charles W. Burrows, then of the Bureau of Standards, was a leader in this work, while Fahy, Sanford and de Forrest have made notable contributions to the subject. It was the writer's privilege to be continuously associated with Dr. Burrows for over twenty years on a committee of the A. S. T. M., dealing with magnetic testing and specifications. At his solicitation I presented a paper before the American Society for Testing Materials in 1914, entitled "Magnetic Habits of Alloy Steels." In this paper I pointed out many anomolous things that had been noted in the previous ten or twelve years. The most noteworthy of these was the discovery that many types of alloy steels are magnetically harder when quenched in oil than when quenched in water, even though their mechanical hardness (Brinell or Shore) was much less in oil than in water. While this was entirely contrary to the generally accepted idea, it did not seem to attract much attention among metallurgists and no one undertook to explain the phenomenon. It had been universally considered that the harder one could make a given steel the lower would be its permeability and the higher its permanence, i. e., the more difficult both to magnetize and to demagnetize. This we found was very far from being the case with most of the ordinary types of pearlitic alloy steels. This infor-

mation had great practical importance and was especially timely for immediately the World War began, tungsten advanced tremendously in price and all that was available was needed for high speed steels. The result was the development of oil-hardening chromium magnet steels which were so nearly equal to the old standard tungsten magnet steels that no user of magnets found it necessary to change his designs or to alter the size of his magnets.

In the same paper the writer suggested the magnetic criterion B_r/H_c, B_r being the usual designation for residual magnetism and H_c the designation for coercive force, or the measure of permanence. It was pointed out that this had been found a very useful factor and had been used for ten years or more before it was made public. In the testing of hardened magnet steels two values are especially important, and they are B_r and H_c. To make complete magnetic determinations of the full hysteresis loop of hardened samples is a laborious undertaking and cannot be considered when large numbers of samples are involved. It is readily appreciated that the knowledge furnished by the hysteresis loop is of great value to the designing engineer who uses permanent magnets. The relation between the B_r and H_c values as expressed by the factor B_r/H_c seems logical and for this factor Doctor Burrows suggested the name "coercivity" from the analogy to the word "permeability" (μ). The analogy is not perfect, however, for it will be recalled that permeability means the ratio of any value of B to the corresponding H on the normal induction curve, while B_r/H_c means one specific ratio taken from the hysteresis curve. I think a better expression would be "specific retentivity," since the ratio really means the average number of magnetic lines of residual magnetism removed by one unit of demagnetizing H. In other words, the term "coercive force" implies that something has been coerced by the force and that something is the residual magnetism.

This suggested criterion did not meet with great approval upon the part of electrical engineers. At various times criticism was voiced by no less distinguished authorities than Dr. E. Gumlich and the late Professor Silvanus Thompson and others. For the most part these critics said that if I really had to introduce a new criterion, why not the product $B_r \times H_c$ and not the quotient B_r/H_c. I am not unmindful of the values of $B_r \times H_c$ in the design

of magnets and magnetic circuits, but the product is not a constant while the quotient is, between values of, say, H=200 to H=500, or higher. While the results of different laboratories testing at different maximum values of H cannot be directly compared, either as to B_r, H_c or $B_r \times H_c$, yet very fair agreement between laboratories might be expected from a comparison of B_r/H_c values. Furthermore, there may be several steels whose $B_r \times H_c$ values are constant and yet the magnets made from these steels will be decidedly different. Let me illustrate:

A single bar of chromium steel was cut into short lengths and the odd lengths were formed into U-shaped magnets and the even lengths were hardened for permeameter tests. The corresponding bars and magnets were carefully hardened at the same time and from the same furnace. In this experiment we were dealing with a single material treated in various ways as to the method of quenching.

Table I

Form & Tests	Treatments		
Bars	1500° F. in water at 120° F.	1500° F. in water at 150° F.	1525° F. in oil
B_r per sq. cm.	9950	9730	8910
H_c	59.7	60.9	66.7
$B_r \times H_c$	594,015	592,557	594,297
B_r/H_c	166.6	159.7	133.4
Magnets			
Initial flux	25,500	26,100	25,200
Flux after aging	19,800	21,400	21,700
% Loss by aging	22.4	18.0	13.9

Here we have, as the result of different heat treatments, three different sets of magnetic values as determined on straight bar samples in the permeameter test. The values for $B_r \times H_c$ are, however, practically identical, while the numerical values for B_r/H_c differ, and in the writer's opinion the smaller the numerical value for a given material, the greater its specific retentivity. The magnets treated in the same way as the permeameter test pieces seem to confirm this opinion for in the initial condition as magnetized, they differ but slightly, but the loss by aging indicates that the highest B_r/H_c suffers most and the lowest B_r/H_c suffers least and in the end the magnet which was lowest in flux as freshly charged is highest after aging. Our $B_r \times H_c$ must not be confused with the value $(BH)_{max.}$ frequently used in British

publications but they are numerically proportional. $(BH)_{max.}$ is a measure of the energy content of the steel available for useful work when used on apparatus designed to give maximum efficiency. The one illustration given above of the use of the B_r/H_c ratio will serve to show how it may be used to advantage in interpreting permeameter tests in terms of possible use values, when the steel goes into various sizes and forms of magnets.

This rather long explanation of the ratio B_r/H_c is made because in what follows we shall make use of this value and more particularly because in my original paper proposing its use, I did not seem to make its significance plain or its possible use and value understood.

Let us now resume the consideration of retained austenite. For over ten years the cause of greater magnetic hardness in oil-quenched alloys frequently came to mind but no explanation of it was ever offered by distinguished metallurgists with whom I discussed the matter at home and abroad. About a year ago, having been honored with the appointment as Henry Marion Howe Memorial Lecturer[1] by the American Institute of Mining and Metallurgical Engineers, it occurred to me that the answer to this question would be a worthy undertaking in memory of my honored teacher and the thought that continually inspired me was to produce results worthy of the man whose memory I was chosen to honor, and the solution of this old problem was the result. In my Howe Lecture I reached three conclusions contrary to generally accepted ideas:

First: In all normally hardened medium or high carbon steels and the usual engineering alloy steels, gamma iron, or austenite, is always present with the martensite. This conclusion is based upon the nature of the volume changes which occur upon tempering hardened steels. A recent paper by Enlund[2] fully confirms this conclusion and extends it to fairly low carbon steels. The still earlier work of Howard Scott[3], M. A. Grossmann[4] and Heindlhofer and Wright[5] leaves little doubt as to this conclusion. I will now go a step farther and predict that some hot rolled alloy

[1]Mathews, "Austenite and Austenitic Steels," Howe Lecture, A. I. M. and M. E., 1925.

[2]Enlund, "On the Structure of Quenched Carbon Steels," *Journal*, Iron and Steel Institute, 1925, No. 1.

[3]Scott, Scientific Papers, Nos. 395 and 396, Bureau of Standards, 1920.

[4]Grossmann, "Brittle Ranges in Low Alloy Steels," *Iron Age*, 1924, p. 149.

[5]Heindlhofer and Wright, "Density and X-ray Spectrum of Hardened Ball Steel," TRANSACTIONS, American Society for Steel Treating, Vol. VII, p. 84, 1925.

steels will be found, when the test is made, to contain substantial amounts of gamma iron.

Even though we may have believed the austenite-martensite transformation was complete upon quenching, yet this first conclusion is easy to accept if we recall how we used to set about obtaining austenite for examination under the microscope. We were told to select a very high carbon steel, say, 1.50 per cent carbon, heat a very small mass of it 2000 degrees Fahr. and quench as quickly as possible in iced brine. By this procedure a mixture of martensite and austenite resulted. We do not recall ever seeing a plain carbon steel totally austenitic, so it appears the retention of austenite is a question of speed of quenching and its amount may be a matter of degree, depending upon speed, and possibly it may, therefore, be present in amounts not recognizable by the microscope.

No, this reasoning is subject to considerable modification, for as the results of our recent investigations we have reached our next conclusion:

Second: In a wide variety of alloy steels, notably those capable of hardening readily in oil, there is more austenite present after oil-quenching than after water-quenching for normal hardening. This conclusion is not so easy to accept. It seems incredible that the relatively slow cooling in oil should retain more gamma iron than the rapid cooling in water. This conclusion, however, is based upon evidence derived from several different methods of attack.

The volume changes which occur upon gradual tempering of hardened steels offer the first proof. When first tempered, steels contract in length due to tempering of the martensite with precipitation of carbides; this continues until temperatures between 400 and 500 degrees Fahr. are reached, when, if austenite be present, expansion begins and continues until all the iron is converted to the alpha form. These actual temperatures vary somewhat with different steels. The steels the writer particularly studied were 2.0 and 3.0 per cent chromium steels of about 0.90 per cent carbon. Comparing the results for both oil and water quenching for both of these steels, it was observed that for water hardening the contraction stage was greater and the expansion stage less than for the oil hardened specimens. This in itself indicates more martensite and less austenite in the water quench.

Next we made magnetic tests upon the steels after tempering at 100-degree Fahr. intervals and it was surprising how the magnetic changes followed the length changes, as the diagram (Fig. 1) will make clear. There is a noticeable tendency for the magnetic differences of oil and water hardened specimens to vanish at a drawing temperature of 600 degrees Fahr. or a little higher.

Since it has been found that many of the industrial alloy

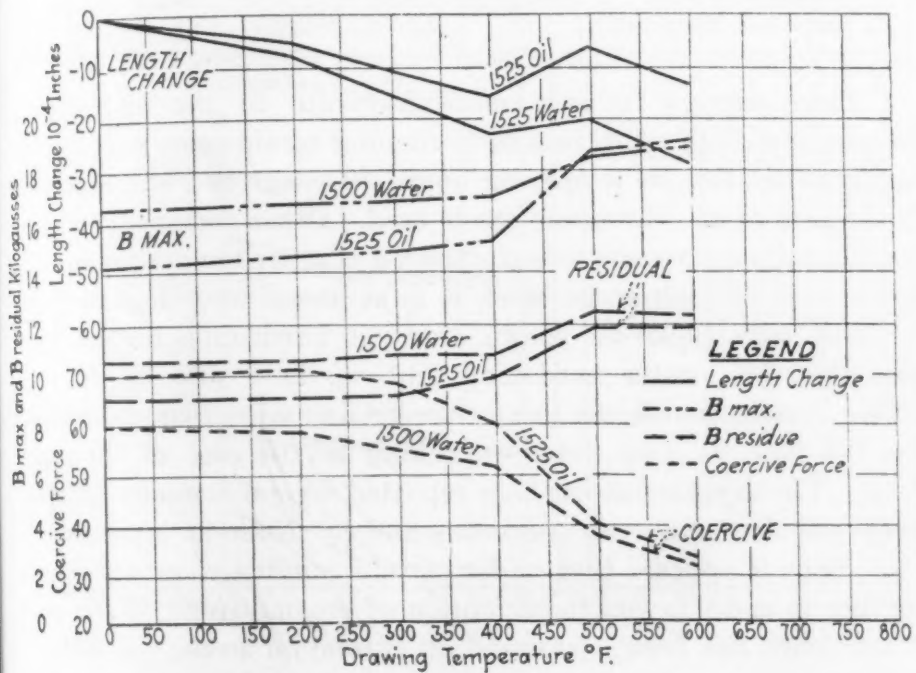


Fig. 1—Effect of Reheating on Length Change and Magnetic Properties of Quenched Chromium Magnet Steel M-31.

steels, whether magnet steels or not, behave in the same way when oil or water hardened, a number of them were tested as to specific gravity as hardened in these two media. It has long been known that hardened steel is lighter than annealed steel, that is, it occupies a greater volume. Martensite is the lightest or most voluminous condition of steel. A hardening which produces the lowest specific gravity may be considered as affording the most complete martensitization possible for that steel. A hardened steel of greater specific gravity must either contain the more voluminous gamma iron or else the hardening has proceeded beyond the martensitic state toward troostite and pearlite. In every case where we have determined the specific gravity as oil and water

quenched, the latter showed the lower value as the following summary shows:

Table II
Specific Gravity

	Oil Quenched	Water Quenched
Chromium Steel No. 1	7.8548	7.8416
Chromium Steel No. 2	7.7996	7.7861
Chromium Steel No. 3	7.8371	7.8302
Tungsten (5 per cent)	8.1292	8.1015
Chromium-Nickel	7.8255	7.8177
Chromium-Tungsten	7.8755	7.8580

These figures indicate more austenite in the oil-hardened samples, but both conditions of hardening retain some gamma iron as the expansion on tempering above 400 degrees Fahr. indicates in the case of the chromium steels used. Other compositions show the austenite-martensite transformation at other temperatures, e. g., in the case of high speed steel, it is at about 1000 degrees Fahr.

Not only have we shown that oil hardening retains more austenite than water hardening, but we have also shown that, within certain limits, the larger size retains more than the smaller size for both oil and water quenching in the case of chromium steels. The experiment has been repeated several times by different observers, with different specimens and by different testing methods. Thus it appears that under certain conditions, retarded cooling due to mass, favors the retention of gamma iron. While most of our work has been performed on chromium steels, yet we have had the same result with tungsten magnet steel in water and we had the test duplicated by the Bureau of Standards. Fig. 2 shows the results for a chromium steel of 0.81 per cent carbon and 2.91 per cent chromium. It also shows the effect of cooling the specimens in liquid air and it will be seen that the largest size, oil-quenched, was most influenced by undercooling and that the properties of the oil hardened samples, after liquid air treatment, quite nearly approach the properties of the water quenched samples. This would indicate that the low temperature has transformed the gamma iron to alpha iron, with an immediate increase in maximum and residual induction and a decrease in coercive force.

This leads us to our third conclusion, namely, that austenite is a cause of increased permanence or retentivity in those alloys

capable of hardening readily in oil. This conclusion may sound strange when it is recalled that austenite or gamma iron is non-magnetic. Possibly it is this property which accounts for the lower maximum and residual induction resulting from oil hardening as compared with water hardening. In this case it is merely

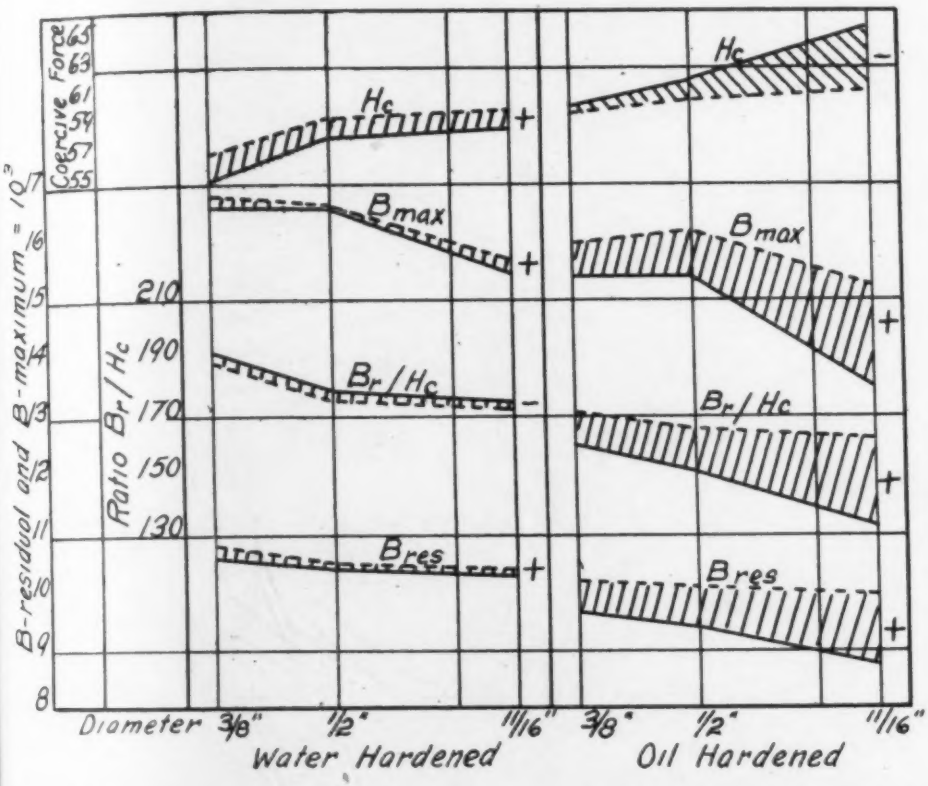


Fig. 2—Effect of Size on the Magnetic Properties and Effect of Liquid Air on Oil and Water-Hardened Chromium Steel.
Note: Full lines represent values before liquid air treatment; Broken lines represent values after liquid air treatment.

a dilutant of the alpha iron, but its effect on coercive force is positive and definite, and when its transformation to alpha iron occurs by liquid air treatment the coercive force immediately drops. The new cobalt magnet steels are strongly austenitic in character since they contain from 15 to 35 per cent cobalt and from 5 to 10 per cent of tungsten, molybdenum, chromium and manganese in various combinations. Some of these steels by overheating become nearly non-magnetic and photomicrograph Fig. 3 shows the structure of one such steel quenched from 2000 degrees Fahr. In this condition it showed only 160 gausses of residual magnetism instead of the customary 9,000 to 11,000 of good per-

manent magnet steel. The structure is pure austenite plus carbides. After immersion in liquid air (photomicrograph Fig. 4) this structure changes to austenite and martensite plus carbides

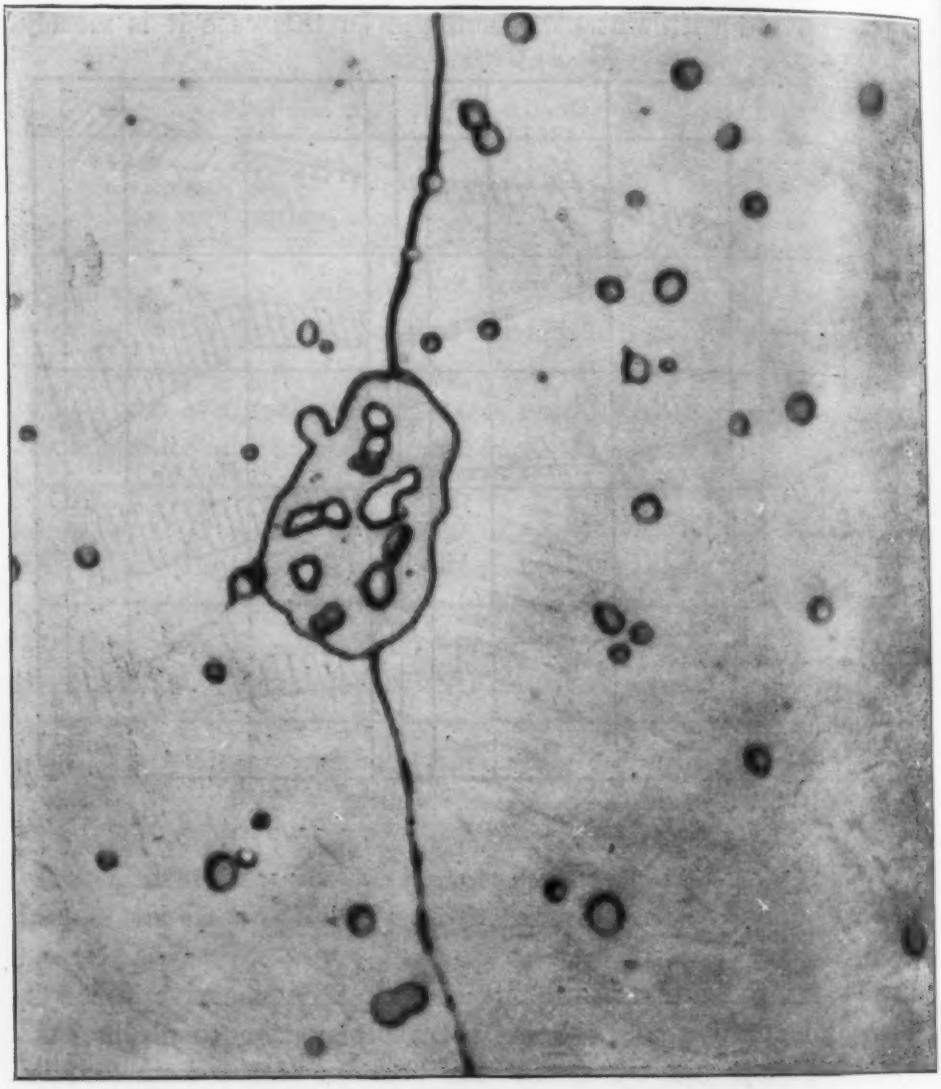


Fig. 3—Photomicrograph of a Cobalt Magnet Steel when Quenched from 2000 Degrees Fahr. In this Condition the Steel Showed Only 160 Gausses of Residual Magnetism. Magnification 3300x.

and the residual magnetism increased to 1500 gausses, a gain of over nine fold, yet it is far short of the normal retained magnetism of the same steel properly hardened, and a second treatment in liquid air failed to produce any marked increase. Just why this is the case I am unable to explain. All the photomicrographs were made for me by F. F. Lucas.

The evidence warranting these three conclusions seems quite convincing, but in order to check them by methods other than my own, I was fortunate in enlisting the assistance of E. C. Bain

Fig. 4—Photomicrograph of the Cobalt Magnet Steel of Fig. 3 After Immersion in Liquid Air. The Residual Magnetism was Increased to 1500 Gausses. Magnification 3300x.

and F. F. Lucas, who employed the methods for which they are so widely known. Identical specimens that had been used in my experiments were broken in two, one portion being given to each man. The steels were chromium steels that had been hardened in oil and in water.

After X-ray examination, Mr. Bain reported the presence of

faint lines in both samples, which were indicative of gamma iron. A further examination warranted him in stating that the oil-hardened specimen showed more gamma iron than the water-hard-

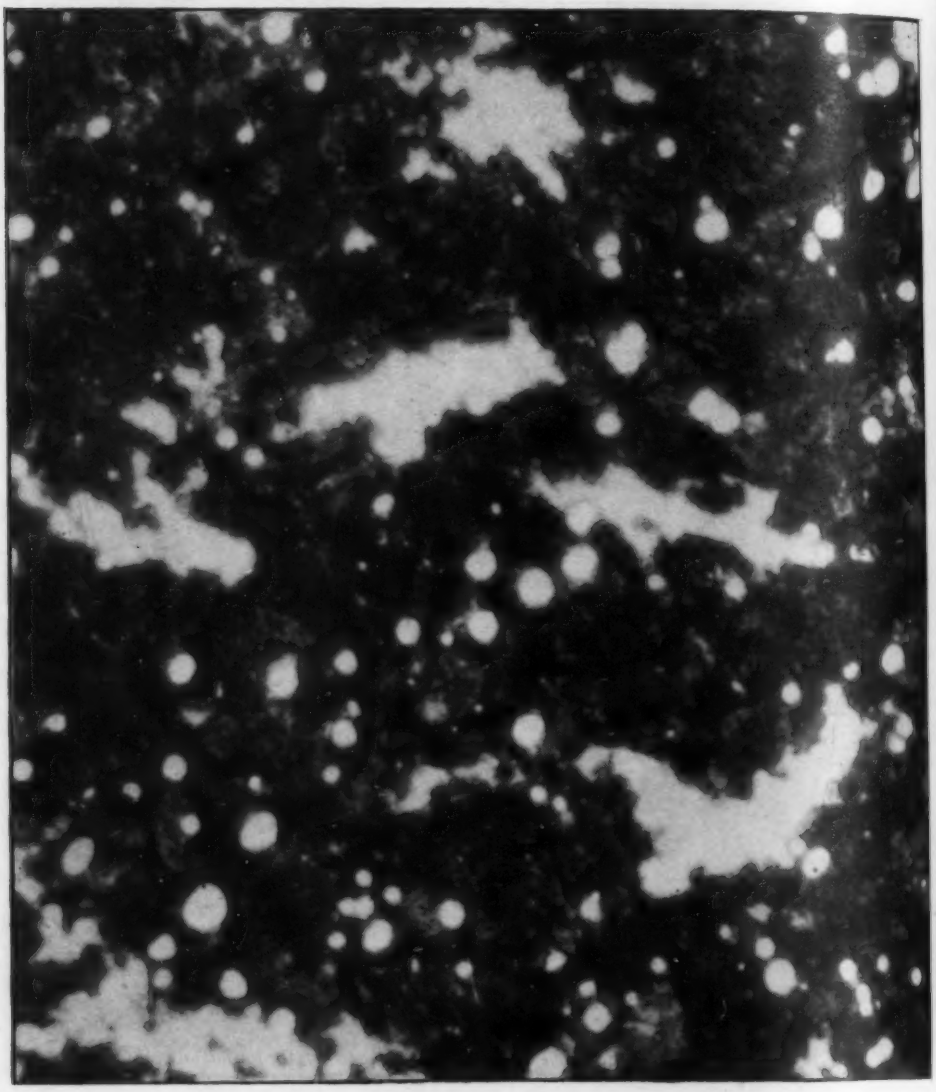


Fig. 5—Photomicrograph of the Cobalt Magnet Steel as Shown in Figs. 3 and 4. Normally Hardened and Etched in Boiling Sodium Picrate. Magnification 3300x.

ened one. He estimated that the gamma iron content was not very great, perhaps six to ten per cent in any case.

Mr. Lucas examined the samples under high power magnification, because low power magnifications are of little value in studying these extremely fine grained steels. There was little difference to be noted after the nitric acid etching, but when etched with

boiling sodium picrate the water-hardened specimen etched much darker than the oil-hardened one. In fact, the latter showed many relatively large patches which did not darken and which

Fig. 6—Photomicrograph of the Cobalt Magnet Steel Shown in Fig. 5 After Immersion in Liquid Air for 4 Hours and then Etched in Boiling Sodium Picrate. Magnification 3230x.

are considered to be austenite. A half dozen different photomicrographs of each of the two specimens could be readily separated into those that represented oil or water-hardening.

In my earlier paper dealing with oil and water-hardening, I tested many types of alloy steels—nickel, nickel-vanadium, chromium-nickel, silico-manganese and chromium-silico-manganese

—most of them several times and in several compositions. In that paper I stated: "Strange to say, it does not hold good for the two types of steel most used for permanent magnets, namely, common open hearth magnet steel of the type represented by carbon 0.60 per cent and manganese 0.75 to 1.00 per cent and high grade tungsten magnet steel of the type, carbon 0.60 per cent and tungsten 5.00 per cent."

These steels have been re-examined. The former does not harden readily in oil, but when the manganese content is higher, from 1.50 to 1.75 per cent, the maximum and residual induction are greatly decreased by oil quenching, while the coercive forces are found to be about equal for oil or water hardening. This, of course, means that the B_r/H_c ratio is in favor of oil quenching. A specific example, carbon 0.62 per cent and manganese 1.55 per cent will illustrate this:

	Quenched in Oil from 1500° F.	Quenched in Water from 1500° F.
B (H=300)	14,300	15,200
B_r	7,700	8,150
H_c	48.5	49.0
B_r/H_c	159.0	166.0

We may consider that when the carbon and manganese are so adjusted that the steel really hardens in oil, such steels fall into the general category of alloy steels as regards the magnetic properties of oil and water quenching.

With tungsten steels, the case is not quite so simple. Two steels were used, one containing carbon 0.70 per cent, tungsten 3.60 per cent and small amounts of silicon, manganese and chromium. The other contained carbon 0.74 per cent and tungsten 5.30 per cent. The first steel was hardened at two temperatures, namely, 1550 and 1600 degrees Fahr. in both oil and water. The results were qualitatively the same and not very different; therefore, only the results at 1600 degrees Fahr. are given in Table III.

From Table III it appears that the steel behaved "normally"; i. e., the residual and maximum induction are lower and the coercive force higher after oil hardening and the specific retentivity B_r/H_c favors the oil treatment.

In the method of transforming residual austenite into alpha iron by tempering, we must, of necessity, temper the martensite first; therefore it seemed wise to bring about this transformation

in another way, namely, by low temperature cooling which is believed to produce the transformation without disturbing the original martensite. The specimens were given a two-hour cooling in liquid air and the changes are given in Table III. We do not know the ideal time or temperature for producing this transformation, or

Table III

Effect of Liquid Air on 3.50 Per Cent Tungsten Steels

Treatment	1600°F. Oil	1600°F. Water	Tested for—
As Quenched	14,600	16,000	B (H = 300) Maximum
After Liquid Air	14,900	15,900	Induction
% Change	+2.05	—.63	
As Quenched	9,280	10,450	B_r, Residual
After Liquid Air	9,700	10,500	Induction
% Change	+4.53	+0.48	
As Quenched	64.0	62.0	H_c, Coercive Force
After Liquid Air	63.0	60.8	
% Change	—1.56	—1.94	
As Quenched	145	169	B_r/H_c
After Liquid Air	154	173	
% Change	+6.20	+2.37	
As Quenched	63	65	Rockwell, C. Hardness
After Liquid Air	64	65	
% Change	+1.59	0	

whether it is quantitatively complete. However, it is at once seen that the changes in the oil-hardened steel are of much greater magnitude than those in the water-hardened steel, and in the case of the maximum induction are actually of the opposite sign.

In the case of the 5 per cent tungsten steel, the results are not quite "regular." While the induction values are lower for oil, so also is the coercive force. This is quite unusual, but it will be noted that even at the high quenching temperature employed (1650 degrees Fahr.) the steel only attained a Rockwell hardness of 55. In B_r/H_c, however, the steel is true to form. Table IV gives the comparisons. From these data, as compared with the 3.50 per cent tungsten steel, the magnitude of the changes induced by liquid air is notable and leads us to suspect that the latter steel is more strongly austenitic after oil hardening. Photomicrograph, Fig. 5, shows the same cobalt magnet steel shown in Figs. 3 and 4, normally hardened and etched in sodium picrate. Magnification 3300X. Note the uncolored white areas and the generally "gray"

color of other portions. Fig. 6 shows the same steel after four hours in liquid air. The white areas have disappeared and only carbides in a very dark field remain. Magnification 3230X.

Fig. 7 is the same steel as shown in Fig. 6, nitric acid etch,

Table IV
Effect of Liquid Air on 5 Per Cent Tungsten Steel

Treatment	1650°F. Oil	1650°F. Water	
As Quenched	13,400	14,900	Tested for—
After Liquid Air	15,050	15,200	B (H=300) Maximum
% Change	+12.30	+2.01	Induction
As Quenched	8,320	9,860	
After Liquid Air	9,840	10,150	B_r Residual
% Change	+18.28	+2.94	Induction
As Quenched	64.0	68.5	
After Liquid Air	63.0	67.0	H_c Coercive Force
% Change	—1.56	—2.19	
As Quenched	130	144	B_r/H_c
After Liquid Air	156	151	
% Change	+20.0	+4.86	
As Quenched	55	64	Rockwell, C. Hardness
After Liquid Air	56	65	
% Change	+1.82	+3.15	

magnification 3230X, and shows a very fine martensite and carbides.

Fig. 8 is that of a regular 3 per cent chromium magnet steel, water-quenched from 1525 degrees Fahr. and etched in nitric acid. The magnification is 3230X. An extremely fine grained martensite is revealed.

The liquid air experiments have furnished valuable confirmatory evidence in regard to the function of austenite in permanent magnetism and the experiments on manganese and tungsten steels show that within certain ranges of composition these steels may be expected to behave like the other pearlitic alloy steels, in respect to oil and water quenching. After all it is not surprising that for any type of alloy steel there are certain ranges of composition within which the retention of austenite is most marked. May it not be that those are the ranges within which greatest commercial uses exist and may it not be that the effect of alloys in increasing the retention of austenite is of primary importance in producing

those qualities which we desire in alloy steels as compared with carbon steels?

We have explained most of the anomalous things referred to

Fig. 7—Photomicrograph of the Cobalt Magnet Steel Shown in Fig. 6 After Being Normally Hardened and then Immersed in Liquid Air for 4 Hours. The Specimen was then Etched with Nitric Acid. Magnification 3230x.

in our paper upon the magnetic habits of alloy steels, but at the same time have raised another question, namely—why does retarded rate of quenching as represented by oil quenching, or as represented by greater mass, increase the retention of gamma iron? The first attempt to answer this question was made by E. C.

Bain[6] in his paper entitled "The Persistence of Austenite at Elevated Temperatures." This explanation is worthy of serious consideration, if for no other reason than because it is Mr. Bain

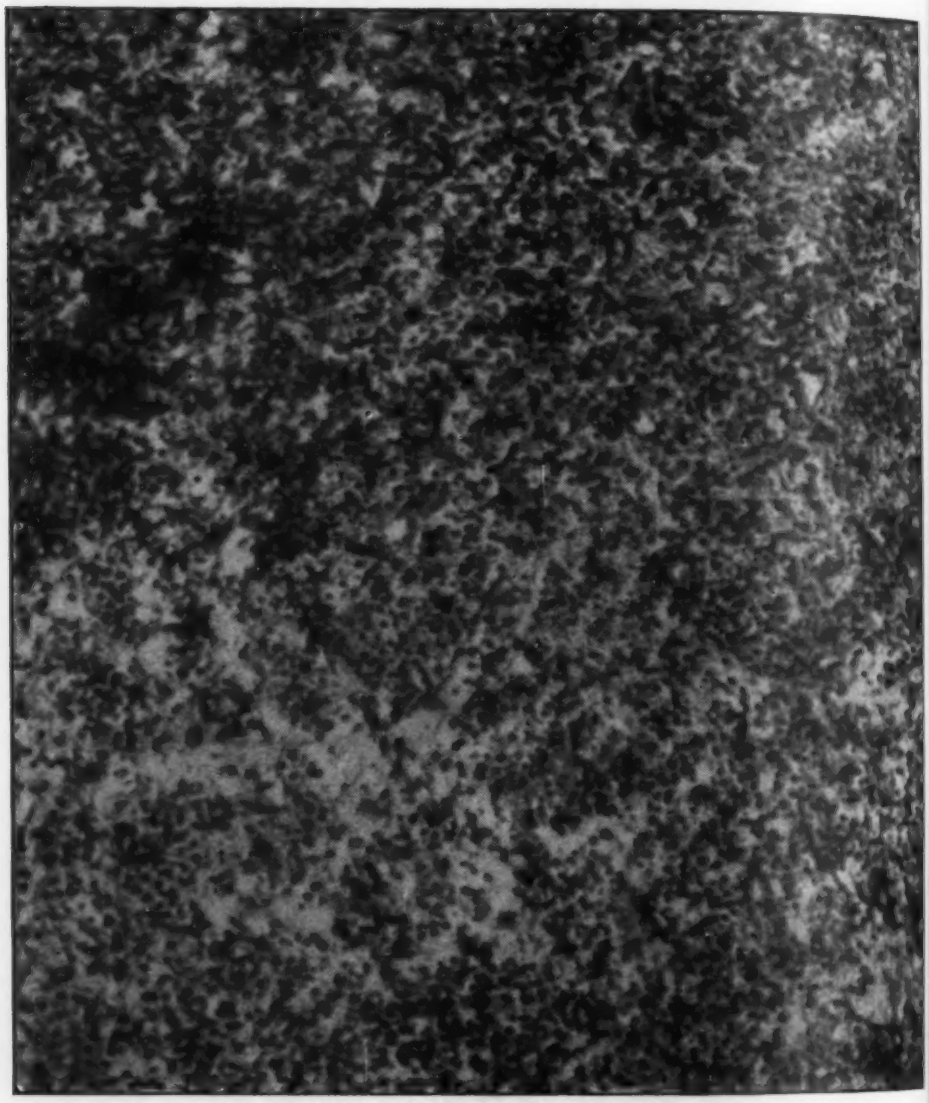


Fig. 8—Photomicrograph of a 3 Per Cent Chromium Magnet Steel Water-Quenched from 1525 Degrees Fahr. and then Etched in Nitric Acid. Magnification 3230x.

who makes the suggestion. The writer has not as yet had an opportunity to study this paper. It has seemed to me that a more careful consideration of quenching stresses rather than quenching speeds may lead to an explanation.

[6]Bain, "The Persistence of Austenite at Elevated Temperatures," TRANSACTIONS, American Society for Steel Treating, 1925, Vol. VIII, p. 14.

The results outlined above are of great interest in connection with permanent magnets, but it is my belief that the importance of these new concepts is of far wider significance in regard to the general subject of hardening and the reasons for the results that are attained under various conditions of quenching and from various compositions. It is but the opening of a new field of research and much remains to be done. I have only made a small beginning and earnestly hope others will assume the future burden. I have no proprietary right to the subject.

What we need is a quantitative measure of the proportions of alpha and gamma iron coexisting in a given material. Possibly the determination of maximum induction is roughly quantitative, the induction being lowered somewhat proportionately to the amount of non-magnetic gamma iron present. We do not know that the temperature of liquid air is necessary or even the best temperature for bringing about the delayed gamma-alpha transformation, or what time is necessary, or whether the transformation is complete in any case. These and many other questions await solution and it is certain that their solution will add greatly to our ability to interpret the hardening problems and results of our everyday experience. As regards permanent magnets, there may be a critical amount of austenite for each composition that yields maximum permanence. Composition, hardening temperature and quenching medium are likely the variable factors to be considered. If we accept the conclusions drawn from the evidence presented herein, we certainly have open to us a wide field for scientific speculation. The future presentation of facts will tell us whether our speculation has been along sound lines or not, and when we have nothing further to speculate about, metallurgy will be a closed book.

Discussion

CHAIRMAN BURGESS: Any paper by Dr. Mathews is always a treat, and I think this is one of the best treats I have ever had in the way of listening to a paper. I suppose all of you were impressed, as I was, at the number of methods of attack and the numerous parameters that Dr. Mathews used in confirming his preliminary suspicions and observations, such as the liquid air quenching method, improved methods of thermal treatment, the use of a very high power microscope, density, mechanical hardness, to say nothing of his beautiful presentation and definition and arrangement of the magnetic qualities, and lastly, the X-ray analysis, all of which contributed to the proving

of the existence of austenite or gamma iron at ordinary temperatures, under certain treatments. The paper is before you for discussion.

Written Discussion:—By W. E. Ruder, Research Laboratory, General Electric Co., Schenectady, N. Y.

The writer's discussion of the paper on permanent magnet steel by Adams and Goeckler was inspired largely by Dr. Mathews' previous work on the effect of retained austenite on coercive force. A better understanding of magnetic phenomena is to be had only by separating, as far as we can, the two factors which we know in permanent magnets as residual (B_r) and coercive force (H_c) and in low loss (soft) magnetic materials as saturation and hysteresis. The writer has shown in previous publications, that the factor of saturation is influenced primarily by the amount of pure ferrite iron present and also by the crystal orientation. Hysteresis, on the other hand, while it is a function of the ferrite present, is more or less independent of the composition of that ferrite, and is a function of the grain size rather than of its orientation. It is evident, then, that magnetic phenomena are dependent upon crystal structure as well as atomic structure.

It must be borne in mind that coercive force is merely a measure of the resistance to change of direction of magnetism. The best conception we have as yet of electron arrangement in an iron atom is that two free electrons, occupying polar positions, appear to be responsible for the magnetic property, so we are not any better off than we were with Ewing's elementary magnet hypothesis. We do have a better conception, however, of the structure of the crystal and knowing the large proportion of space present it is not so hard as it once was to conceive of an actual reversal taking place in solid material under the action of atomic forces.

Comparatively small changes in coercive force may be caused by mechanical strain or by solid solution of some kinds of atoms, particularly carbon. This we can easily imagine as being due to disalignment of the atoms and the reduction of their mutual action, just as we know that the more we have in perfect alignment, i. e., the larger the crystal, the lower the coercive force. The several hundred-fold increase in coercive force, such as we have in permanent magnets, however, calls for a much more potent force than mere space lattice distortion and for that reason, in the writer's previous discussion, he has taken Dr. Mathews' evidence of retained austenite as a possible explanation.

The outstanding fact in this connection is that the presence of the carbon atom seems to be necessary. The effect of gamma iron, as such, has not had sufficient investigation but as far as known it is very small. The carbon atom, however, seems to form the necessary interlinkage between the austenite and the ferrite and thereby to give the austenite the necessary frictional influence upon the revolution of the ferrite atom to make it necessary to impress a very high magnetic force on it before it will turn.

Such a conception calls for an atomic relationship between the alpha iron in quenched steels and the retained austenite, the existence of which may be difficult to prove but seems to be worth while investigating.

The extremely fine grain of the ferrite in quenched steels has, undoubtedly, an important contributing influence upon the coercive force, but the

most important factor is that the rate of cooling is so controlled that the maximum amount of ferrite be retained together with just enough austenite in proper dispersion to influence the reversal of the ferrite atoms. Too much austenite could have no good effect but would merely serve to cut down the remanence, while too little would decrease the coercive force out of proportion to its beneficial influence upon the remanence.

There is another way in which the grain size may influence the coercive force. If we assume that the austenite influences the revolution of the ferrite atoms only at the boundaries between the two kinds of crystals by a kind of interlinkage due to the presence of the carbon atoms, the smaller the grain, the greater will be this interaction and the difficulty in assuming any atomic dispersion of austenite disappears.

In closing, I would like to ask Dr. Mathews if he has any evidence on the effect of quenching in mercury as compared with these other various methods. He seems to have touched them all, so he possibly has tried the mercury. The reason I ask is because we have had some rather unexplainable results recently in the study of some cobalt steels in comparing the effect of mercury quench with a water quench.

DR. J. A. MATHEWS: I have limited the quenches to water and oil at various temperatures. I have not investigated the effects of mercury or any other reagents. The oil was the ordinary soluble No. 2.

E. C. BAIN: In 1922, I experimented with a number of nickel steels which were kindly made for me by the Vanadium Alloys Steel Company of Latrobe, containing 20 per cent nickel and quite a variety of carbon contents. At that time I quenched these steels in water and in oil and found that in the whole series the amount of austenite present in the oil quenched specimens exceeded that which was found in the water quenched steels. At the time I did not receive a great deal of enthusiasm from the men with whom I was working, and I laid the experiments away in the pressure of other work. Now, you can imagine my delight when I found that Dr. Mathews had taken an interest in this phenomenon, and I revived my work on the behavior of the two quenches in these steels. I found that at one critical balance of nickel and carbon the oil quench gave what I thought to be about 90 per cent austenite and 10 per cent martensite, whereas the water quench gave almost the opposite ratio. That was a fortunate composition to work with, so I set about for an explanation, and the explanation to which Dr. Mathews referred so flatteringly a moment ago is merely this.

We have been able to show conclusively that the hardening of austenitic steels, both chromium steels and manganese steels, by cold work, is due to the production of alpha iron, probably in a form precisely or very nearly like martensite obtained in the quench. I attribute that to the development of a sufficient mobility by the cold work to permit the new rearrangement of atoms in the more stable form. If that be true, then the enormous stresses which are developed in steels at the quench would provide a certain mobility.

The water quench, as we know, produces much more severe stresses; otherwise, we would not have the cracking of steels in the water quench and the failure to crack in oil. This mobility, then, permits a rearrangement after

the stress is applied. The stress no doubt comes at a time when the austenite is particularly susceptible to changing over to alpha iron, that is, at some elevated temperature, perhaps early in the quench. The point, then, is that the more severe stresses of the water quench provide a certain amount of cold work on that austenite which would have a tendency to be retained thus converting it to martensite.

DR. V. N. KRIVOBOK: Mr. Chairman, ladies and gentlemen. I fancy that the paper of Dr. Mathews cannot, properly speaking, be discussed; it can only be appreciated. I am sure I voice the opinion of the audience when I make such a statement. I had the privilege of having the paper of Dr. Mathews for a very short time last night, and I have made a few notes on the questions that seemed particularly interesting to me.

The true scientific spirit of Dr. Mathews can be truly appreciated in view of his own statement that as long as he has been associated with the steel industry, which has been over twenty years, this question of magnetism and austenite retained in steels on quenching has been occupying his attention.

When speaking of the retained austenite, Dr. Mathews makes the following statement:—"The volume changes which occur upon gradual tempering of hardened steel offer the first proof. When first tempered, steels contract in length due to tempering of the martensite, with precipitation of carbides. This continues until the temperature between 400 and 500 degrees Fahr. is reached, when, if austenite is present, expansion begins and continues until all the iron is converted into the alpha form."

My knowledge of the subject is very limited, as compared to that of Dr. Mathews and this frank admission permits me to ask the following question: "How does Dr. Mathews explain the fact that the change of martensite to troostite and of austenite to alpha iron takes place in the order named and not vice versa? With my limited knowledge of molecular physics, it seems to me that the reverse order would prevail. The splendid work of F. F. Lucas on the nature of martensite and troostite bears this out.

The finding of Dr. Mathews that there is more austenite present in steels quenched in oils opens a new and rich field for research. It is possible that austenite or gamma iron is stable even below room temperature and also at the boiling point of water and some work now under way strongly points in that direction. The results are not yet entirely conclusive.

The conception that the retained austenite is the cause of increased permanence is certainly intensely interesting, and almost startling in view of our knowledge that austenite is non-magnetic. It is sincerely hoped that Dr. Mathews will soon have more to say on the subject.

DR. ZAY JEFFRIES: Mr. Chairman and Gentlemen, I would like to use these findings of Dr. Mathews as a splendid example of the consequences of drawing conclusions too hastily in research.

The effects of the oil and water quench in low carbon steels in producing a greater mechanical hardness by water quenching than is obtained by oil quenching, and the explanation that the water quench produced more martensite, and less troostite than the oil quench, sort of fixed in our minds the general proposition that oil quenching would be responsible for the formation of

troostite on the quench, or even sorbite, if the piece were large enough. Now, no doubt many of us were hampered in our conclusions by having that fact so firmly fixed in our minds. Then, when the study of alloy steels came and the lower mechanical hardness was obtained by oil quenching than was obtained by water quenching, what was more natural than to conclude that the causes of that lower mechanical hardness by oil quenching were the same as those for the low carbon steel? Dr. Mathews has liberated us from this thought and has turned our attention to an entirely new field of thought, which will of course be very far-reaching in its effects.

Mr. Bain in his discussion may possibly have forgotten a little incident in our experiments that is, I think, very significant. We were trying to produce manganese steel of the high manganese variety, 13 per cent manganese, as completely austenitic as possible. So we selected a small piece, about a quarter of an inch square and an inch long, and prepared some very special brine, exceedingly cold, I think it was calcium chloride solution, and quenched the sample from a high temperature. To our surprise, it came out quite magnetic, whereas pieces quenched under identical conditions in ordinary water could not be lifted with a magnet.

We were at a great loss to explain that at the time, and, in fact, did not arrive at any satisfactory explanation as to why that should be. We naturally supposed that the more rapid quench had produced some martensite, but it was an unusual finding. Now, the work of Dr. Mathews, of course, would indicate that the retention of austenite by a mild quench is a common and not an unusual occurrence in certain steels. We did not recognize it as a common occurrence and it required Dr. Mathews' generalization to provide a simple explanation. I hope to offer some additional remarks as a discussion of the next paper by Dr. Hanemann and Miss Schrader, and may say something further about Dr. Mathews' results at that time.

DR. ANCEL ST. JOHN: Just one word, and not particularly pertinent to the question of austenite, but to compliment Dr. Mathews on introducing, I believe, a more extensive type of co-operative research than we have been accustomed to, namely, where a man of his distinction calls in to his assistance men like Mr. Bain and Mr. Lucas, so as to extend the field of the investigation to cover all the possible types of evidence. It seems to me that if there would be less, if I may use the word, "caginess", about what research men are trying to do and more cooperation between research men who have interests along similar lines, we might very well proceed much more rapidly and much more effectively toward the true understanding of nature's secrets with respect to our ferrous materials than we are proceeding at present.

DR. S. L. HOYT: In reference to the microstructure, did the oil-quenched steels have a finer grain size than the water quench steels?

DR. J. A. MATHEWS: I can not say that I noticed any great difference in the fineness of the grain. Mr. Lucas, who made most of these observations, would perhaps give some light on that. They are so extremely fine in both cases that it is very difficult to identify under the microscope any distinct grains. As to what Dr. Krivobok said, do I understand you think the austenite changes first and the martensite second?

DR. V. N. KRIVOBOK: My question is, Sir, as follows: on quenching the steels which are normally martensitic at room temperature, austenite changes into martensite, with precipitation of carbides. Then as stated in your paper another change takes place, that of tempering of martensite. This continues, you indicate, until a temperature between 400 and 500 degrees Fahr. is reached, when, if austenite is present, expansion begins and continues until all of the iron is converted into the alpha form. Did I understand that the change of martensite accompanied by the precipitation of carbides takes place first? If we understand that the austenite is in a very unstable condition, or I rather say a metastable condition, would you not expect some change in austenite before the carbides come out of solution?

DR. J. A. MATHEWS: Mr. Bain's paper on the subject of the persistence of austenite is rather good evidence on that. I think it is proven conclusively that austenite can remain very stable in different steels up to as high as the austenite of high speed steel at the 1100 degree Fahr. draw, or higher. I neglected to say that after my chromium steels had been treated in liquid air, we repeated the experiment of tempering in the ordinary way, and found no expansion whatever taking place beween 400 or 500 degrees Fahr., either for the oil or water quenched specimens. That single experiment would seem to indicate that the conversion of gamma iron to alpha iron was quite complete after liquid air treatment.

With the tungsten steels that was not quite the case; it may be complete or incomplete. Some expansion took place in the three and one-half per cent tungsten steel, and in the case of the five per cent tungsten steel there was practically neither expansion nor contraction; one showed 0.0001 inches expansion in four inches, for the water quench, and 0.0002 inches for the oil quench. How to interpret that, I do not know. There may be a small amount of gamma iron still left after the first liquid air treatment.

It should be remembered that the lines in my diagram illustrating volume changes are really composite curves made up of two components as was shown by Grossmann. Each is made up of a contraction and an expansion, possibly taking place simultaneously, one due to tempering martensite and one due to the transformation of gamma iron to alpha iron. The latter tendency is greater than the former at from 400 to 500 degrees Fahr. and the net result is an expansion in this range.

DR. O. E. HARDER: In the case of the drawing experiments at different temperatures, how long were the specimens drawn?

DR. J. A. MATHEWS: They were held at temperature for one-half hour. They were drawn in the oil bath where the temperatures permitted and in the salt bath above that.

Author's Closure

The appreciative discussion of so many able men is most gratifying. I assume they are convinced that the experimental data substantiates my conclusions and if these new concepts prove of value to our physical metallurgists we may expect that they will respond by clearing up some of the unsolved problems which still trouble us.

WELDING STEEL TUBING AND SHEET WITH CHROMIUM-MOLYBDENUM WELDING WIRE[1]

By F. T. Sisco and H. W. Boulton

Abstract

In welding chromium-molybdenum steel seamless tubing and chromium-vanadium steel sheet, chromium-molybdenum welding wire produces a weld which has a more desirable and uniform structure than low carbon welding wire. In welding chromium-molybdenum steel tubing to plain carbon steel tubing chromium-molybdenum steel welding wire is not greatly superior and may even be inferior to low carbon welding wire. Welded chromium-molybdenum steel tubing has a soft area about 3/4 inches from the weld due to localized annealing, at which spot failure in tension will occur unless the structure is made uniform by heat treatment. Heat treatment consisting of quenching in water followed by tempering greatly improves the structure of welded chromium-molybdenum steel tubing and chromium-vanadium steel sheet, at and near the weld. With tempering temperatures of 1000 degrees Fahr. (538 degrees Cent.) and above, the ultimate strength and elongation are much superior to the untreated tubes and sheet. Chromium-molybdenum steel welding wire is more difficult to melt and work than low carbon wire, but if done by a skillful operator produces a weld that is, ordinarily, perfect in every case.

The effect of heat treatment is not so important in its improvement of physical properties as in the refinement and equalization of the structure at the weld, although quenching followed by a high tempering temperature improves the ultimate strength and elongation sufficiently to make it advisable to heat treat all welded chromium-molybdenum steel tubes and chromium-vanadium steel sheet, if possible.

Introduction

IN the construction of the modern airplane, the framework of the fuselage is seamless steel tubing. The longerons (horizontal members) which extend from nose to tail are braced at intervals

[1]Published by permission of the Chief of Air Service, War Department.

Of the authors, F. T. Sisco is metallurgist and H. W. Boulton is test engineer, Engineering Division, Air Service, War Department, McCook Field, Dayton, Ohio.

by diagonals of seamless tubing welded to them. In the construction of these various welded members making up the fuselage, two main factors enter: (1) materials; and (2) workmanship. By employing skillful and experienced welders the second factor may be made practically constant. The work outlined in the present paper was done to investigate the possibility of effecting an improvement in the materials and included a study of the various kinds of materials and their properties after welding. The effect

Table I

Analyses of Materials

	C	Mn	S	P	Cr	Mo	V
Chromium-molybdenum steel tube	0.32	0.56			0.93	0.23	
Medium carbon steel tube	0.31	0.45	0.038	0.040			
Low carbon steel tube	0.18	0.49	0.030	0.040			
Chromium-vanadium steel sheet	0.14	0.50	0.028	0.040	0.77		0.23
Low carbon steel welding wire	0.03	0.48					
Chromium-molybdenum steel welding wire	0.28	0.61			1.14	0.95	

Note—Phosphorus percentages all below 0.040 per cent

of heat treatment on the physical properties of the welded tubes and sheet and on the structure of the weld was also investigated.

While it was originally planned to confine the welding experiments to seamless tube only, it was thought advisable to make at the same time a study of welded chromium-vanadium steel sheet.

Although the results obtained by this investigation cannot be called complete and conclusive, enough was accomplished to show that welding with chromium-molybdenum wire could be done successfully on a commercial scale, and to indicate that in some cases such welds should give better service than welds made with regular low carbon wire.

Chromium-molybdenum steel in the form of wire suitable for welding is not available at the present time. The wire used in this investigation was supplied through the kindness of the Air Reduction Company, Jersey City, N. J., who made up a small coil for use in these experiments.

Material

The material used in this investigation included three grades of seamless steel tubing and one grade of sheet stock. The composition of the material, together with the analyses of the two grades of welding wire, are shown in Table I.

Tubing and sheet of only one size was used. The former was cold drawn seamless tubing 1 inch in outside diameter and 0.036 inch wall. The sheet was 0.036 inch in thickness. The low carbon and the chromium-molybdenum steel welding wire were both $\frac{1}{16}$ inch in diameter.

The low carbon steel welding wire was copper-coated and

Table II

Physical Properties of Welding Wire

Welding Wire Class Designation	Low Carbon, A	Copper-Coated	Chromium-Molybdenum, Uncoated B	
Specimen No.	1	2	1	2
Gage length, in.....	10	10	10	10
Diameter, in.	0.062	0.062	0.062	0.062
Ultimate Strength, lbs. per sq. in.	57,350	67,150	118,000	116,700
Elongation in 10 in., per cent	3.6	1.6	1.6	2.1
Fracture	Cup	Cup	Cup	Cup

was taken directly from the welder's stock. The chromium-molybdenum steel wire was uncoated. Both grades of wire were soft drawn, that is, they had probably been given one draft after annealing. The physical properties of the two grades of wire are given in Table II.

The chromium-molybdenum steel tubing was in the normalized

Table III

Required Physical Properties of Steel Tubing and Sheet (Air Service Specifications)

	Tensile Strength, minimum, lbs. per sq. in.	Yield Point, minimum, lbs. per sq. in.	Elongation in 2 in., per cent
Chromium-molybdenum steel tubing	95,000	60,000	..
Medium carbon steel tubing.....	80,000	60,000	18
Low carbon steel tubing.....	55,000	36,000	22
Chromium-vanadium steel sheet....		Not specified	

Note—Tubes are required to pass a crushing test without failure.
Sheet is required to pass a 180-degree bend over a radius equal to thickness of sheet without cracking

condition. The chromium-vanadium steel sheet was furnace-annealed. The three grades of tubing and the sheet were from stock purchased under Air Service Specifications. The physical properties of the material as received conformed in every case to the requirements noted in Table III.

It was desired to have the chromium-molybdenum steel weld-

ing wire of the same composition as the tubes. However, the wire furnished contained 0.95 instead of 0.25 per cent molybdenum and as no other chromium-molybdenum steel wire could be obtained the work was done with the material available.

Method of Procedure

The method of procedure in carrying on the work was divided into four parts. These are:

1. Welding the tubes and sheet
2. Heat treatment
3. Physical tests
4. Metallography.

Welding

In preparation for welding, the tubes were cut into 8-inch lengths and one end squared up on a lathe. The sheet was cut into 1-inch strips, 6 inches long and similarly machined on one end. As the chromium-molybdenum steel wire was not in the proper condition for arc welding, the welds were all made by the oxy-acetylene torch. No special precautions were taken. The work was done in identically the same manner as production- and repair-welding on fuselage construction. The operator who did the welding was exceptionally skillful and in every case produced welds of perfect workmanship.

The welding procedure with the class and letter designation was as follows:

Schedule I—Not to be heat treated

Tube Welding

Class 1

A—Chromium-molybdenum steel tube welded to chromium-molybdenum steel tube, using low carbon steel welding wire.

B—Same as A but using chromium-molybdenum steel welding wire.

Class 2

A—Chromium-molybdenum steel tube welded to medium carbon steel tube, using low carbon steel welding wire.

B—Same as A but using chromium-molybdenum steel welding wire.

Class 3

A—Chromium-molybdenum steel tube welded to low carbon steel tube, using low carbon steel welding wire.

B—Same as A but using chromium-molybdenum steel welding wire.

Sheet Welding

Class 4

A—Chromium-vanadium steel sheet welded to chromium-vanadium steel sheet, using low carbon steel welding wire.

B—Same as A but using chromium-molybdenum steel welding wire.

In Class 1 above, nine welds of A and nine welds of B were made. In Classes 2, 3, and 4 three welds of A and three welds of B were made.

Schedule II—To be heat treated

Tube Welding

Classes 11, 12, 13

Chromium-molybdenum tube welded to chromium-molybdenum tube, using chromium-molybdenum welding wire.

Sheet Welding

Classes 14, 15

Chromium-vanadium steel sheet welded to chromium-vanadium steel sheet, using chromium-molybdenum steel welding wire.

In Class 11, 12, and 13 six welds of each were made. In Class 14 and 15 ten welds of each were made.

In addition to the welding outlined above, in which the walls of the tubes were all 0.036 inch, two 8-inch sections of chromium-molybdenum steel tubing with a ⅛-inch wall, were welded with chromium-molybdenum steel wire and two with low carbon steel welding wire. The welding procedure differed in this case in that the squared ends of the tubes to be welded were first beveled at an angle of 45 degrees before welding. The two welds of the heavy walled tubing were made to serve as a check on hardness results.

It was desired to determine the Rockwell hardness values of the tubes in the vicinity of the weld, and it was considered probable that due to the thinness of section in the tube with an 0.036 inch wall erratic tests might result. In case errors in hardness tests became apparent, the thick walled tubes could be used as a check.

Heat Treatment

As the time available in investigating the welding of tubes and sheet was limited, it was necessary to confine the heat treatment to chromium-molybdenum steel tubes welded to chromium-molybdenum steel tubes using chromium-molybdenum steel welding wire only, and to chromium-vanadium steel sheet welded to chromium-vanadium steel sheet in a like manner. The chief purpose in heat treating the welded material was to eliminate the soft area discovered near the weld in the untreated specimens of the same class and to equalize the grain structure at and near the weld. The improvement of strength and ductility which resulted from heat treatment, while important, is not so essential as uniformity of properties and the elimination of any spots of weakness caused by local overheating in welding.

The tubes and sheet welded according to Schedule II were heat treated in the following manner:

Class 11—Tubes

Heated to 1625 degrees Fahr. (885 degrees Cent.), held 30 minutes, quenched in water. Tempered at 800 degrees Fahr. (425 degrees Cent.) for 30 minutes and cooled in air.

Class 12—Tubes

Quenched as in Class 11, tempered at 1000 degrees Fahr. (540 degrees Cent.) for 30 minutes and cooled in air.

Class 13—Tubes

Quenched as in Class 11, tempered at 1250 degrees Fahr. (680 degrees Cent.) for 30 minutes and cooled in air.

Class 14—Sheet

Heated to 1625 degrees Fahr. (885 degrees Cent.), held 30

minutes, quenched in water. Tempered at 1000 degrees Fahr. (540 degrees Cent.) for 30 minutes and cooled in air.

Class 15—Sheet

Quenched as in Class 14, tempered at 1250 degrees Fahr. (680 degrees Cent.) for 30 minutes and cooled in air.

In heating for quenching and drawing, an electric muffle furnace was used. The temperature was controlled to 10 degrees Fahr. by a recording potentiometer and automatic current regulators. The tubes and sheet of each class were wired into bundles and placed in the furnace when the temperature was about 1300 degrees Fahr. Heating to 1625 degrees Fahr. was accomplished in about one hour; the material was then held 30 minutes at this temperature. The water for quenching was approximately 60 degrees Fahr. Each bundle of tubes and sheet was quenched *in toto*, thus insuring the same rate of heat extraction in each piece of the same class.

Physical Tests and Hardness

The tubes and sheet were tested in tension with a 20,000-pound tensile testing machine. The tubes were not machined but were held by friction grips after plugging each end with a tight fitting steel plug. The sheet specimens were machined to ½-inch, as shown in Fig. 3. This was done to be certain that the strip would not fracture in the grip.

Both tubes and sheet were punch-marked for taking elongation on a 2, 4, and 8 inch gage length. The proportional limit was taken with a Berry strain gage reading to 0.0002 inch. It was not necessary to take the proportional limit on all specimens. Those samples on which the proportional limit was not taken were tested for yield point. This was taken when the specimen elongated 0.01 inch in a gage length of 2 inches.

The proportional limit was taken from the stress-strain curve in which load in pounds was plotted against deflection in ten thousandths of an inch. The proportional limit was that point at which the curve first departed from a straight line, where deflection was no longer directly proportional to the load.

Due to the thinness of section of the tubes, Rockwell hardness tests were the only accurate values possible. These were taken at

⅛-inch intervals, beginning at the weld and extending 1½ inches to the right and to the left. These tests were made only to detect possible differences in hardness and thus determine if the heating that the tube had undergone in welding had caused local hardening or softening in the vicinity of the weld. Hardness tests were made only on chromium-molybdenum steel tube welded to chromium-molybdenum steel tube, Class 1A and 1B and Class 12. One specimen of chromium-molybdenum steel tube welded to chromium-molybdenum steel tube with chromium-molybdenum steel wire was tested for Rockwell hardness as quenched but not tempered.

In making the Rockwell hardness tests, the $\frac{1}{16}$-inch ball and the B scale were used on the untreated tubes (Table IX). For the heat treated tubes the diamond point and C scale were used.

Metallography

Specimens for microscopic examination were cut longitudinally through the weld, including the weld and about ¼-inch of the tube on both sides. Specimens to show the normal structure of the steel were taken also longitudinally near the end of the tube or sheet and at least 6 inches from the weld. The specimens were all mounted in soft solder and were polished successively on an emery grinding belt and on 0, 00, and 000 French emery paper. Finish polishing was with levigated alumina on English "kitten's ear" broadcloth. The specimens were examined unetched to detect the presence of any slag or other inclusions, and to note any unsoundness or oxidation in and around the weld. After this examination, the specimens were etched in alcoholic nitric acid (2 per cent). Representative photomicrographs were taken at magnifications of 100 and 500 diameters.

Results

The results of the work may be summarized under four heads:

(1) Welding
(2) Physical properties
(3) Uniformity of hardness near the weld
(4) Metallography.

Welding

All of the welds made were perfect. This was due primarily

to the skill of the welder. It was observed that the chromium-molybdenum steel welding wire did not flow so readily under the torch as the regular low carbon steel welding wire. The welder expressed the opinion that chromium-molybdenum steel wire was more difficult to melt and work, but that no trouble should be experienced with it after the operator became accustomed to its use.

It was observed that when low carbon steel welding wire was used the melted metal ran through the junction of the two pieces welded and formed a uniform weld on the under side as well as on the upper side. With chromium-molybdenum steel welding wire this did not occur. The melted welding wire ran through the junction in places but did not form a weld of uniform thickness on the under side of the piece. This may be responsible, in part, at least, for some of the welded sheet breaking in the welds after heat treatment (Fig. 3).

Due to the thinness of section of the tubes and sheet the welding could be done very rapidly, consequently, the welded ends of the tubes and sheet became heated to bright redness only in the vicinity of the junction. One inch away from the junction the metal was at a black heat.

Physical Properties (Not Heat Treated)

The physical properties of the welded tubes and sheet are summarized in Tables IV, V, VI, and VII. Table IV gives the properties as welded (not heat treated) of the chromium-molybdenum steel tubes welded to chromium-molybdenum steel tube, using low carbon steel welding wire (Class 1A) and chromium-molybdenum steel wire (Class 1B). All of the fractures occurred about ½ inch from the weld. The location and appearance of the fractures are shown in Fig. 1.

Table V gives the properties as welded (not heat treated) of the chromium-molybdenum steel tubes welded to medium carbon steel (Class 2A and 2B), and to low carbon steel tubes (Class 3A and 3B), using low carbon steel and chromium-molybdenum steel welding wire. The properties of the chromium-vanadium steel sheet welded to chromium-vanadium steel sheet (Class 4A and 4B), using both grades of welding wire, are also noted. The location and appearance of the fractures are shown in Fig. 1.

Table IV

Physical Properties of Welded Tubes—Not Heat Treated

Welding	Chromium-Molybdenum Tube to Chromium-Molybdenum Tube						Chromium-Molybdenum Tube to Chromium-Molybdenum Tube					
Welding Wire	Low Carbon						Chromium-Molybedenum					
Class (from Fig. 2)	1-A						1-B					
Specimen No.	1	2	3	4	5	6	1	2	3	4	5	6
Type of Specimen	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube
Diameter, original, in....	1.001	1.000	1.000	1.000	0.998	0.999	1.000	1.000	1.001	1.002	0.997	0.999
Thickness of wall, in....	0.033	0.034	0.032	0.033	0.034	0.033	0.033	0.034	0.033	0.033	0.033	0.032
Proportional Limit, lbs. per sq. in.....	52,490	52,320	51,520	..	..	..	44,990	44,850	41,990	..	..	..
Yield Point, lbs. per sq. in.....	..	..	..	67,790	69,200	71,990	..	..	..	73,990	75,890	70,900
Ultimate strength, lbs. per sq. in.....	101,400	102,000	103,050	98,990	99,900	100,100	100,100	100,050	100,100	101,000	102,500	103,200
Elongation in 2 in., per cent	4.5	4.5	4.5	2.5	3.0	4.0	3.5	5.0	4.0	4.0	3.0	4.0
Elongation in 8 in., per cent	1.12	1.12	1.25	0.62	0.87	1.12	1.00	1.37	1.12	1.12	0.87	1.12
Location of fracture.....	½ in. from weld											
Character of fracture....	Square											

per cent	1.12	1.12	1.25	0.62	0.87	1.12	1.00	1.37	1.12	1.12	0.87	1.12
Location of fracture						½ in. from weld						
Character of fracture						Square						

Table V

Physical Properties of Welded Tubes—Not Heat Treated

Welding	Chromium-Molybdenum Tube to Medium Carbon Steel Tube				Chromium-Molybdenum Tube to Low Carbon Steel Tube				Chromium-Vanadium Steel Sheet to Chromium-Vanadium Steel Sheet			
Welding Wire	Low Carbon		Chrome-Mo		Low Carbon		Chrome-Mo		Low Carbon		Chrome-Mo	
Class Fig. 1	2-A		2-B		3-A		3-B		4-A		4-B	
Specimen No.	5	6	7	8	9	10	11	12	13	14	15	16
Type of Specimen	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Sheet	Sheet	Sheet	Sheet
Diameter, original, in.	1.003	1.003	1.005	1.003	1.001	1.001	1.003	1.002	0.756	0.748	0.739	0.749[1]
Thickness of wall, in.	.036	0.037	0.038	0.037	0.037	0.037	0.037	0.036	0.037	0.036	0.036	0.036[2]
Proportional limit, lbs. per sq. in.[3]	36,600	37,400	34,650	37,600	24,520	21,400	26,700	25,640	35,800	39,050	38,700	39,500[3]
Ultimate strength, lbs. per sq. in.	66,500	63,800	63,200	68,200	49,800	48,650	50,200	51,300	51,900	60,400	57,500	61,800
Elongation in 2 in., per cent	28.0	21.0	30.5	27.0	47.5	47.0	46.0	44.5	13.5	15.0	13.5	10.0
Elongation in 8 in., per cent	11.12	10.75	11.12	10.00	20.36	19.50	16.86	18.62	..	..	..	..
Location of fracture	3 in. from weld	2½ in. from weld	2½ in. from weld	2 in. from weld	3 in. from weld	3 in. from weld	3 in. from weld	2½ in. from weld	¾ in. from weld	1 in. from weld	¾ in. from weld	1½ in. from weld
Character of fracture	Square	Diagonal	Diagonal	Diagonal	Jagged	Irregular	Irregular	Irregular	Diagonal	Diagonal	Diagonal	Diagonal

[1]Width of sheet in inches
[2]Thickness of sheet in inches
[3]Proportional limit for tubes; Yield Point for sheet

Table VI

Physical Properties of Chromium-Molybdenum Steel Tubes Welded to Chromium-Molybdenum Steel Tubes with Chromium-Molybdenum Welding Wire—Heat Treated

Class	11				12				13			
Heat Treatment	1625° F. Quenched in Water Tempered at 800° F.				1625° F. Quenched in Water Tempered at 1000° F.				1625° F. Quenched in Water Tempered at 1250° F.			
Specimen No. (Fig. 2)	A	B	C	D	A	B	C	D	A	B	C	D
Type of Specimen	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube	Tube
Diameter, original, in.....	0.998	1.000	0.997	0.999	0.999	0.998	0.999	1.00	0.995	0.997	0.999	0.998
Thickness of wall, in.....	0.033	0.035	0.034	0.035	0.035	0.033	0.033	0.034	0.035	0.033	0.035	0.033
Proportional limit, lbs. per sq. in.....	..	122,600	111,700	113,200	94,400	100,400	100,300	..	66,380	64,900	66,200	..
Ultimate strength, lbs. per sq. in.....	161,700	151,500	155,000	155,700	135,800	140,400	140,750	146,200	108,200	109,100	105,000	111,500
Elongation in 2 in., per cent....	4.0	1.0	3.0	3.5	10.0	7.5	11.0	8.0	17.5	17.0	17.5	14.0
Elongation in 8 in., per cent...	2.75	0.62	1.37	2.0	5.12	3.12	5.37	5.0	7.75	8.5	7.88	7.75
Location of fracture	1 in. from weld	2½ in. from weld	At weld	At weld	1½ in. from weld	¾ in. from weld	⅜ in. from weld	2 in. from weld	1½ in. from weld	2 in. from weld	1½ in. from weld	3½ in. from weld
Character of fracture	Spiral	Spiral	Square	Square	Jagged	Spiral	Jagged	Spiral	Jagged	Jagged	Jagged	Jagged

	from weld	from weld	At weld	At weld	from weld	from weld	from weld	from weld	from weld	from weld	from weld	from weld	from weld	
Character of fracture	Spiral	Spiral	Square	Square	Jagged	Spiral	Jagged	Spiral	Jagged	Jagged	Jagged	Jagged		

Table VII

Physical Properties of Chromium-Vanadium Steel Sheet Welded to Chromium-Vanadium Steel Sheet with Chromium-Molybdenum Welding Wire—Heat Treated

Class	14							15						
Heat Treatment	1625° F. Quenched in Water. Tempered at 1000° F.							1625° F. Quenched in Water. Tempered at 1250° F.						
Specimen No. (Fig. 2)	A	B	C	D	E	F	G	A	B	C	D	E	F	G
Type of Specimen	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet	Sheet
Original width, in.....	0.505	0.506	0.501	0.510	0.512	0.506	0.504	0.504	0.501	0.500	0.499	0.502	0.503	0.502
Gage, in.....	0.036	0.036	0.036	0.033	0.036	0.036	0.035	0.035	0.035	0.036	0.036	0.035	0.034	0.034
Yield point, lbs. per sq. in.....	89,800	93,300	66,600	77,270	81,460	67,000	81,670	73,720	77,000	72,370	72,400	72,870	68,700	72,620
Ultimate strength, lbs. per sq. in.....	135,800	133,400	88,700	142,500	135,600	129,500	111,100	87,400	125,500	122,200	89,100	85,350	114,600	130,600
Elongation in 2 in., per cent....	2.0	2.5	1.5	0.50	3.5	2.0	1.5	0.50	3.50	4.50	2.0	3.0	1.5	4.0
Elongation in 4 in., per cent....	1.5	1.5	0.75	0.50	2.0	1.5	1.0	0.50	4.50	3.25	1.0	1.75	1.5	2.25
Location of fracture	2 in. from weld	⅛ in. from weld	At weld	2 in. from weld	⅛ in. from weld	Part in weld	At weld	At weld	1½ in. from weld	Next to weld	At weld	Next to weld	2 in. from weld	Next to weld
Character of fracture.....	Diagonal	Diagonal	Square	Diagonal	Diagonal	Irregular	Square	Square	Diagonal	Diagonal	Square	Diagonal	Diagonal	Diagonal

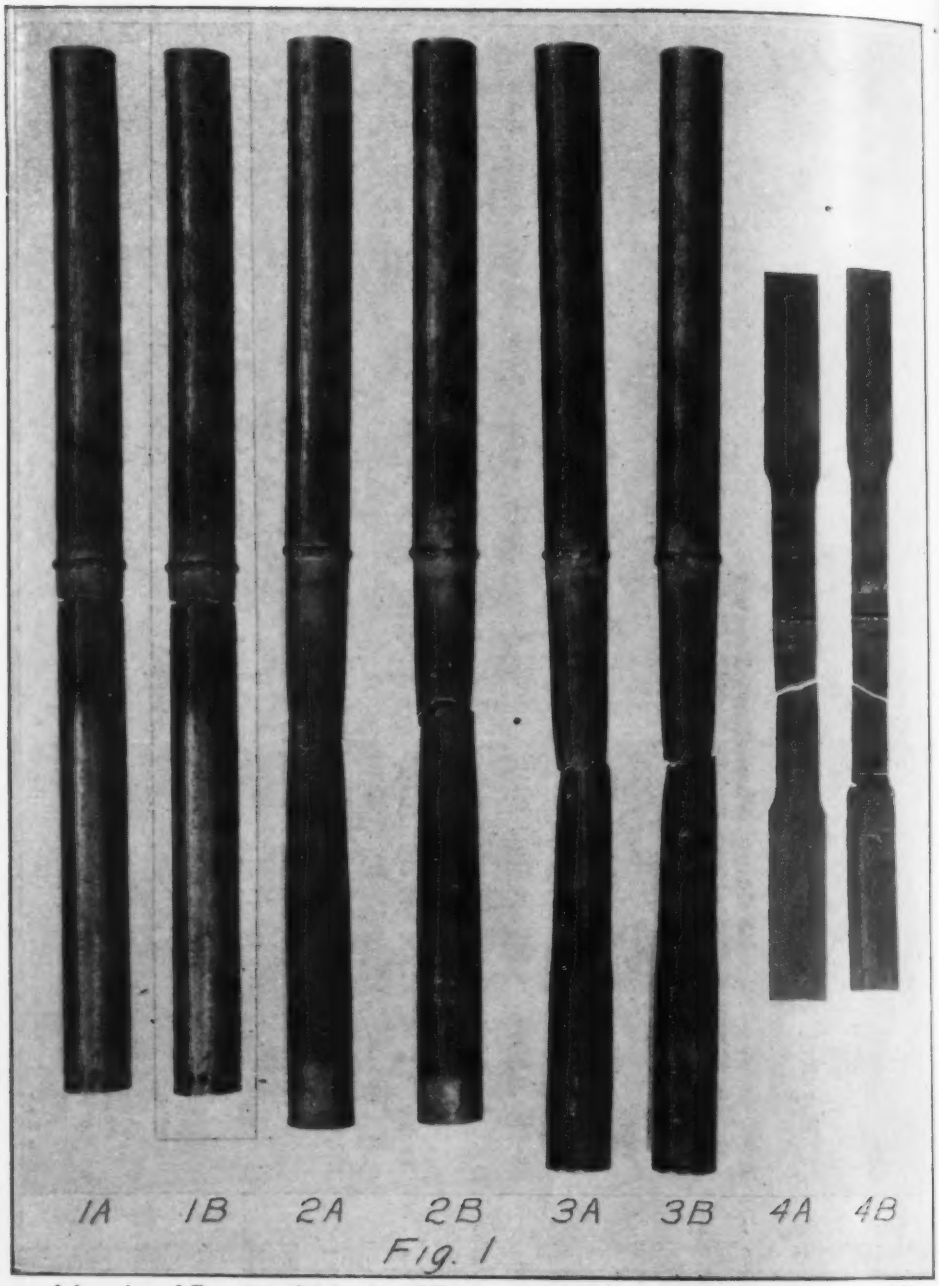


Fig. 1

1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B
Cr-Mo. Tube welded to Cr-Mo. Tube	Cr-Mo. Tube welded to Cr-Mo. Tube	Cr-Mo. Tube welded to 1035 Tube	Cr-Mo. Tube welded to 1035 Tube	Cr-Mo. Tube welded to 1015 Tube	Cr-Mo. Tube welded to 1015 Tube	Cr-V. Sheet welded to Cr-V. Sheet	Cr-V. Sheet welded to Cr-V. Sheet
Low Carbon Welding Wire	Cr-Mo. Welding Wire	Low Carbon Welding Wire	Cr-Mo. Welding Wire	Low Carbon Welding Wire	Cr-Mo. Welding Wire	Low Carbon Welding Wire	Cr-Mo. Welding Wire

Fig. 1—Location and Appearance of Fractures of Welded Chromium-Molybdenum and Carbon Steel Tubing, and Chromium-Vanadium Sheet—Not Heat Treated.

In Classes 2 and 3 fractures occurred in the carbon steel tube and at a considerable distance from the weld (Fig. 1). This was to be expected as the carbon steel tubes had normally much less strength than the chromium-molybdenum steel tubes.

The welded chromium-vanadium steel sheet fractured close to the weld in about the same location as the welded chromium-molybdenum tubes, which lead to the supposition that in these two classes (Class 1 and 4) a soft area existed ½ to 1 inch from the weld. In the case of the welded tubes, this was verified by Rockwell hardness tests.

The physical properties of all the specimens as welded (not heat treated) were fairly uniform; only in the case of the welded chromium-vanadium steel sheet (Class 4A) did any noticeable discrepancy appear. In every case the physical properties were satisfactory for the material tested. None of the specimens broke in the weld. This was to be expected, as there is considerably more metal at the weld. In order to get an accurate check on the strength of the weld, it would have been necessary to machine off the excess metal here before the specimens were tested. This was not done because welded tubes are placed in service as welded and it was desired to duplicate service conditions as closely as possible.

Physical Properties (Heat Treated)

The physical properties of the chromium-molybdenum steel tubes welded to chromium-molybdenum steel tubes after quenching and tempering are given in Table VI. In general, the physical properties are satisfactory, although lower in proportional limit, ultimate strength, and elongation than tubes of approximately the same composition not welded and similarly heat treated (Table VIII). In only two instances (Class 11C and 11D) did fracture occur directly in the weld and then with no sacrifice of strength or ductility. In contrast to the same tubes similarly welded but not heat treated, the fractures in the heat treated tubes (Fig. 2) were erratic in location. This led to the supposition, which was confirmed by the hardness tests, that the soft spot existing in the tubes as welded and causing fracture to occur at the same location each time (Class 1B, Fig. 1) had disappeared after heat treatment. The best combination of physical properties results from drawing temperatures between 1000 and 1250 degrees Fahr.

Chromium-molybdenum steel tubing welded to chromium-

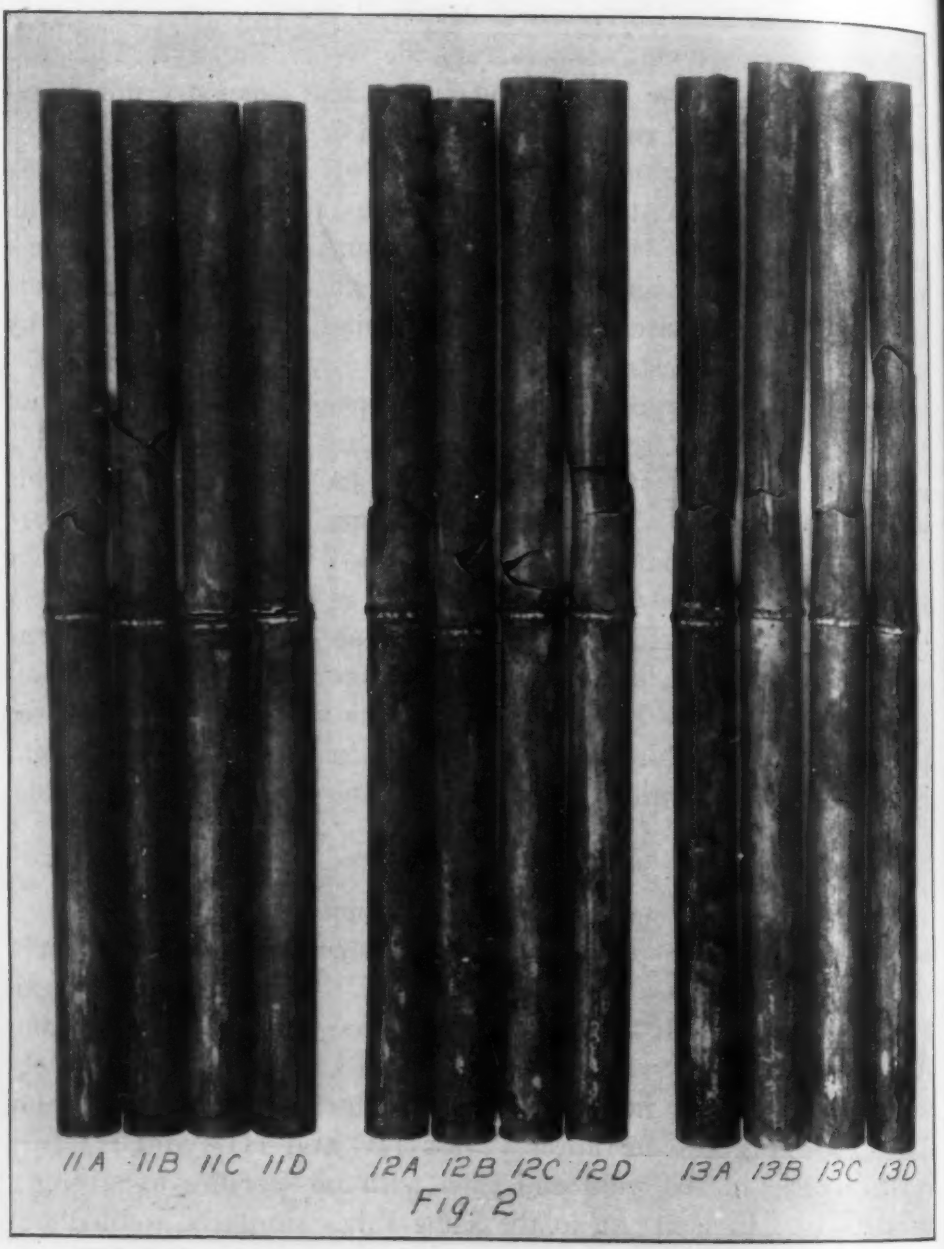


Fig. 2—Location and Appearance of Fractures of Welded Chromium-Molybdenum Tubing —Heat Treated. These Welds are Chromium-Molybdenum Tubes Welded to Chromium-Molybdenum Tubes with Chromium-Molybdenum Welding Wire. All Tubes were Heated to 1625 Degrees Fahr. for 30 Minutes and Quenched in Water. Group 11A to 11D was Tempered at 800 Degrees Fahr. Group 12A to 12D was Tempered at 1000 Degrees Fahr. Group 13A to 13D was Tempered at 1250 Degrees Fahr.

molybdenum steel tubing with chromium-molybdenum steel wire shows such a decided improvement when heat treated that members of this material should always be heat treated if possible.

The only possible objection to heat treatment is warpage in quenching, which may become serious in tubes of such thin section.

Results of the physical tests on the heat treated chromium-vanadium steel sheet welded to chromium-vanadium steel sheet were erratic (Table VII). In six out of fourteen tests the speci-

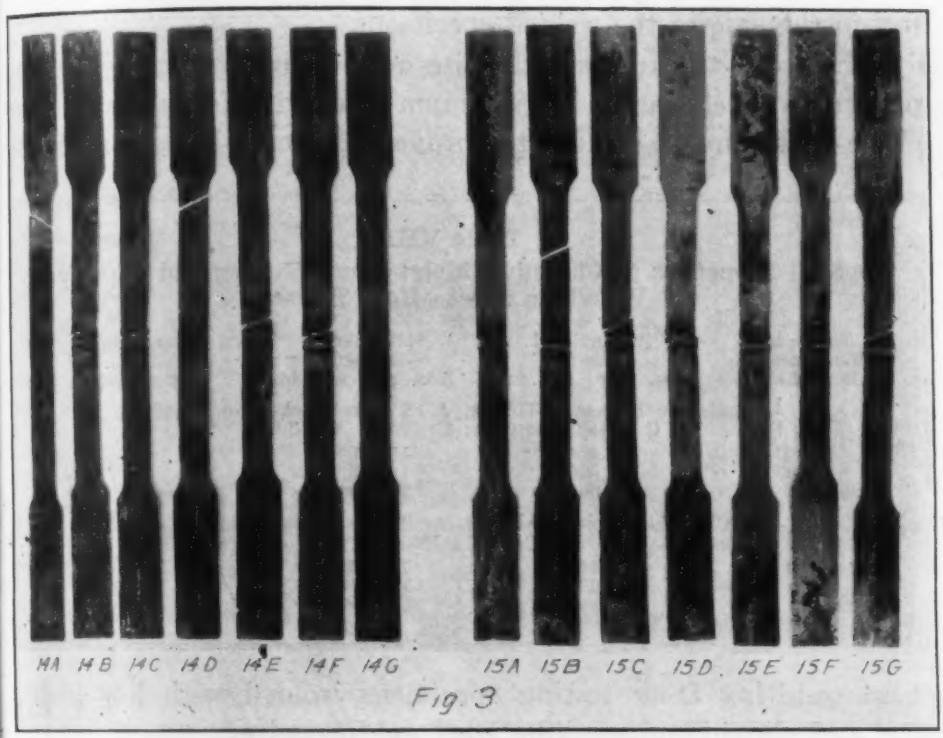


Fig. 3—Location and Appearance of Fractures of Welded Chromium-Vanadium Sheet—Heat Treated. These Welds are Chromium-Vanadium Sheet Welded to Chromium-Vanadium Sheet with Chromium-Molybdenum Welding Wire. All Specimens were Heated to 1625 Degrees Fahr. and Quenched in Water. Group 14A to 14G was Tempered at 1000 Degrees Fahr. Group 15A to 15G was Tempered at 1250 Degrees Fahr.

men fractured either wholly or partially in the weld (Fig. 3). When this occurred, the ultimate strength was approximately 70 per cent of the normal strength. The results given in Table VII indicate that chromium-vanadium steel sheet is not satisfactorily welded with chromium-molybdenum steel wire, although there is no doubt that the welded member is stronger than if welded with ordinary low carbon steel wire. A factor entering into the results shown in Table VII is the failure of the melted chromium-molybdenum steel welding wire to run through the junction uniformly and form a weld on both sides of the sheet.

The properties developed by the welded and heat treated

specimens of sheet (Table VII) may be compared with physical properties of heat treated sheet of the same material and gage but not welded, shown in Table VIII. It will be noted that in those cases where the welded specimen developed its full strength, the ultimate strength was as high as for sheet not welded. The elongation is somewhat less and the proportional limit very much less in the case of the welded specimens.

In order to express a definite opinion regarding the welding properties of chromium-molybdenum steel wire for use with chromium-vanadium steel sheet, the properties should be compared with

Table VIII

Physical Properties of Chromium-Molybdenum Tubing and Chromium-Vanadium Sheet—Heat Treated

Tempering Temperature Deg. Fahr.	Proportional Limit, lbs. per sq. in.	Ultimate Strength, lbs. per sq. in.	Elongation in 2 in., per cent
Chromium-Molybdenum Tubing, A. S. Specification No. 10,231 C 0.34; Mn 0.52; Cr 0.94; Mo 0.31			
800	150,000	180,000	8
1000	125,000	145,000	12
1200	90,000	115,000	20
Chromium-Vanadium Sheet, A. S. Specification No. 10,206 Approximate Analysis—C 0.22; Mn 0.65; Cr 1.00; V 0.18			
800	105,000	145,000	3
1000	108,000	130,000	4
1200	95,000	115,000	5

those resulting from testing specimens welded with low carbon steel and chromium-vanadium steel welding wire.

Uniformity of Hardness Near the Weld

The Rockwell hardness results taken in the vicinity of the weld are given in Table IX for the untreated tubes and in Table X for the treated tubes. In the main, Tables IX and X are self-explanatory. In Table IX, the soft spot in the tubes is marked by an x. (See Table IX.) It will be noted that the soft spot occurs at a distance of ½ to ⅞ inch from the center of the weld. This was the location of the fracture in all of the specimens tested in Class 1A and 1B. It is evident that heating for welding has had an annealing effect on the tube in this limited area. This annealing effect has been quite pronounced, as shown by the decided drop in hardness in this area.

The hardness of the heat treated tubes is fairly uniform, espe-

Table IX

Rockwell Hardness of Welded Chromium-Molybdenum Tubes—Not Heat Treated

Class Welding Stations	Wire	Regular Tube—0.036 inch				Heavy Walled Tube—0.125 inch—Used as check			
		1-A Low Carbon		1-B Chromium-molybdenum		1-A Low Carbon		1-B Chromium-molybdenum	
		Left	Right	Left	Right	Left	Right	Left	Right
Center of weld		66		106		No result		94	
1	⅛ in.	81	78	101	103	75	78	104	..
2	¼ "	102	102	101	101	90	85	85	75
3	⅜ "	102	102	101	102	93	94	96	102
4	½ "	96	100	96	93 x	92 x	86 x	96	103
5	⅝ "	90 x	93 x	86 x	88 x	80 x	90 x	87 x	96
6	¾ "	88 x	87 x	92 x	94 x	95	98	95	89 x
7	⅞ "	93 x	93 x	94	96	96	98	94	93 x
8	1 "	96	96	96	99	97	98	96	96
9	1⅛ "	95	97	97	100	97	98	98	96
10	1¼ "	95	97	96	99	97	102	100	100
11	1⅜ "	96	97	97	100	..	..	..	..

The "x" notes location of the soft area.
Hardness tests made with a ⅛ inch ball and B scale.

cially in the case of the specimen quenched but not drawn (Table X). In both specimens tested there was no soft area apparent; the hardness varied but little from end to end. The location of the fractures in Fig. 2 confirms the uniformity of hardness in that they were erratic in position, a decided contrast to the fractures of the untreated tubes which all occurred in the soft area, as illustrated by the first two tubes in Fig. 1.

Metallography of Welded Tubes and Sheet (Not Heat Treated)

The structures of the chromium-molybdenum steel, medium carbon steel, and low carbon steel tubes are shown in Figs. 4, 5, and 6, and of the sheet in Fig. 7. The structures shown are satisfactory and representative of the material before welding and heat treating. The grain size is small and uniform. No inclusions could be detected in the unetched specimen.

Table X

Rockwell Hardness of Welded Chromium-Molybdenum Steel Tubes—Heat Treated

Specimen		Regular Tubes .036 in. Wall			
Heat Treatment		1625° F. Quenched Water Not Tempered		1625° F. Quenched Water Tempered at 1000° F.	
Welding Wire		Chromium-Molybdenum		Chromium-Molybdenum	
Stations		Left	Right	Left	Right
Center of weld		46		18	
1	⅛ in.	46	44	25	25
2	¼ "	48	45	27	25
3	⅜ "	48	47	26	19
4	½ "	48	46	26	20
5	⅝ "	47	48	26	20
6	¾ "	47	47	25	20
7	⅞ "	46	48	26	20
8	1 "	47	50	25	20
9	1–⅛ "	47	49	26	20
10	1–¼ "	47	47	26	19
11	1–⅜ "	47	47	26	19
12	1–½ "	49	..	25	18

Hardness tests made with diamond point and C scale.

Figs. 8 and 9 show the structure at the junction of the chromium-molybdenum steel tube and the low carbon steel welding wire in the first case, and the chromium-molybdenum steel welding wire in the other case (Fig. 9). Both welds are very good; the one with the chromium-molybdenum steel wire (Fig. 9) has a finer structure than that of the carbon steel welding wire. The structure shown in Fig. 9 should have better physical properties than that shown in Fig. 8.

In Figs. 10 and 11 are shown the structures at the junction between the medium carbon steel tube and low carbon steel welding wire (Fig. 10) and chromium-molybdenum steel welding wire. The grain size of the carbon steel tube shows the effects of heating for welding in the large pearlite grains surrounded by a ferrite network. The grain growth in the case of the medium carbon steel tube at the weld is much greater than with the chromium-molybdenum steel tube (compare Fig. 10 with Fig. 8 and Fig. 11 with Fig. 9). The structure of the low carbon steel welding wire (Fig. 10) is coarse, while that of the chromium-molybdenum steel welding wire is fine (Fig. 11). There is apparently some ferrite segregation shown in Fig. 11 at the junction of the tube and welding metal. In both welds (Figs. 10 and 11) the union is perfect.

Figs. 12 and 13 show the weld between the low carbon steel tube and the low carbon steel welding wire (Fig. 12) and the low carbon steel tube and chromium-molybdenum steel wire (Fig. 13). In these, the weld with the low carbon steel welding wire (Fig. 12) is more homogeneous. A rather sharp dividing line is apparent between the low carbon steel tube and the chromium-molybdenum steel wire in Fig. 13. A peculiarity of the latter weld, shown in Fig. 13, is the fine grain structure of the low carbon steel tube, especially when contrasted with the structure of the low carbon steel welded with low carbon steel wire in Fig. 12.

In Fig. 13, the fine-grained structure of the chromium-molybdenum steel welding wire is noticeable. This fine grain was characteristic of all the welds made with this material and is a strong point in its favor. In general, a fine grain indicates better physical properties than a coarse grain.

Fig. 14 illustrates the weld between the chromium-vanadium steel sheet and low carbon steel welding wire, and Fig. 15, the weld between the chromium-vanadium steel sheet and chromium-molybdenum steel welding wire. Again the structure of the chromium-molybdenum steel welding wire is very fine and the weld perfect. There is no doubt but that chromium-molybdenum steel wire produces a better weld than low carbon steel wire, from the standpoint of microscopic structure.

Comparing the general character of the various welds, as shown by the photomicrographs, it may be stated that chromium-molybdenum steel welding wire produces a weld having the most desirable structure, with chromium-molybdenum steel tube and

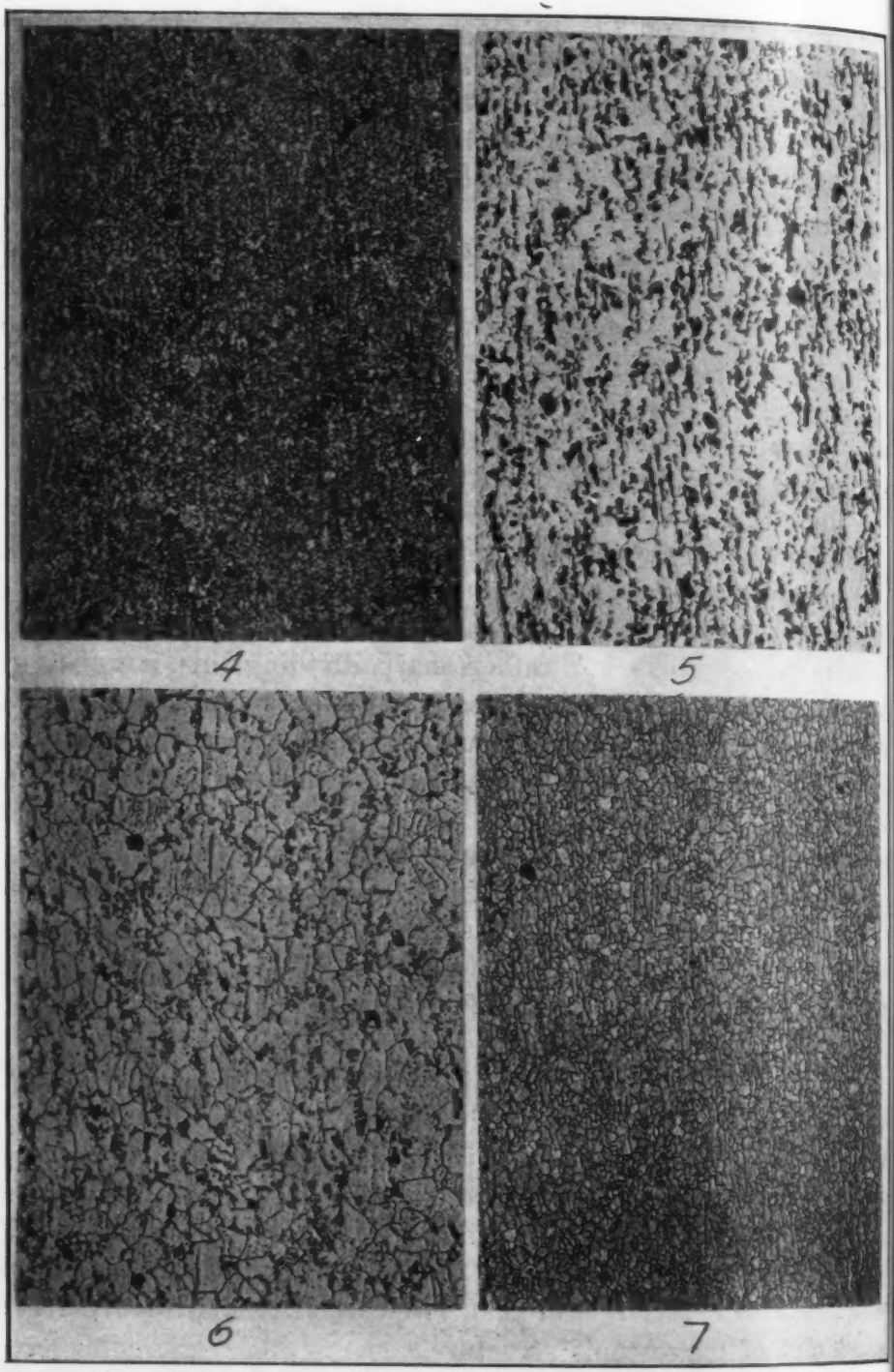


Fig. 4—Photomicrograph of the Average Structure of a Chromium-Molybdenum Steel Tube Before Welding—Not Heat Treated. Fig. 5—Photomicrograph of the Average Structure of a Medium Carbon Steel Tube Before Welding—Not Heat Treated. Fig. 6—Photomicrograph of the Average Structure of a Low Carbon Steel Tube Before Welding—Not Heat Treated. Fig. 7—Photomicrograph of the Average Structure of a Chromium-Vanadium Steel Sheet Before Welding—Not Heat Treated. All Magnifications 100 X.

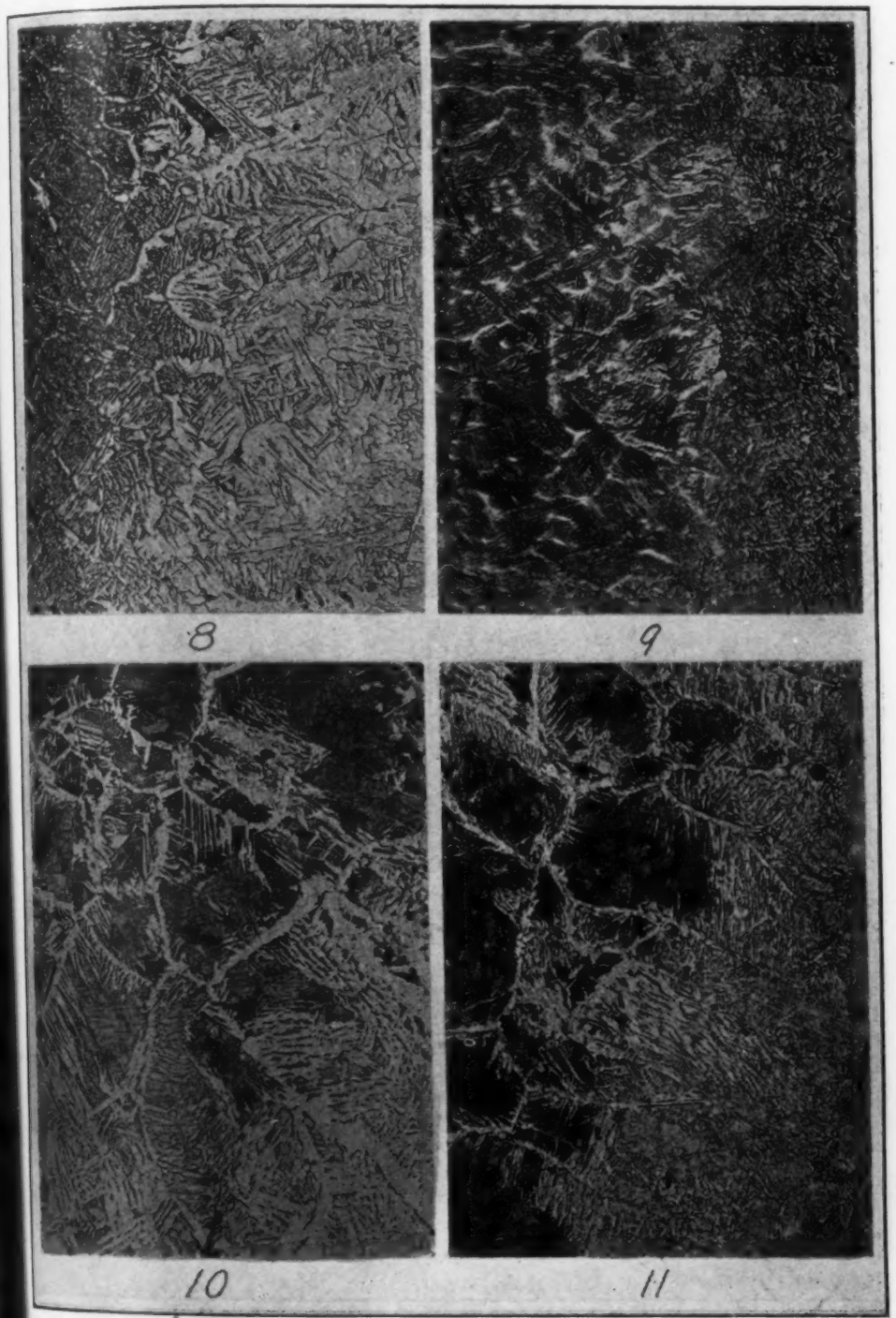


Fig. 8—Photomicrographs of the Structure at the Weld of a Chromium-Molybdenum Steel Tube Welded with Low Carbon Steel Welding Wire—Not Heat Treated. Fig. 9—Photomicrograph of the Structure at the Weld of a Chromium-Molybdenum Steel Tube Welded with Chromium-Molybdenum Steel Welding Wire—Not Heat Treated. Fig. 10—Photomicrograph of the Structure at the Weld of a Medium Carbon Steel Tube Welded with a Low Carbon Steel Welding Wire—Not Heat Treated. Fig. 11—Photomicrograph of the Structure at the Weld of a Medium Carbon Steel Tube Welded with a Chromium-Molybdenum Steel Welding Wire—Not Heat Treated. All Magnifications 100 X.

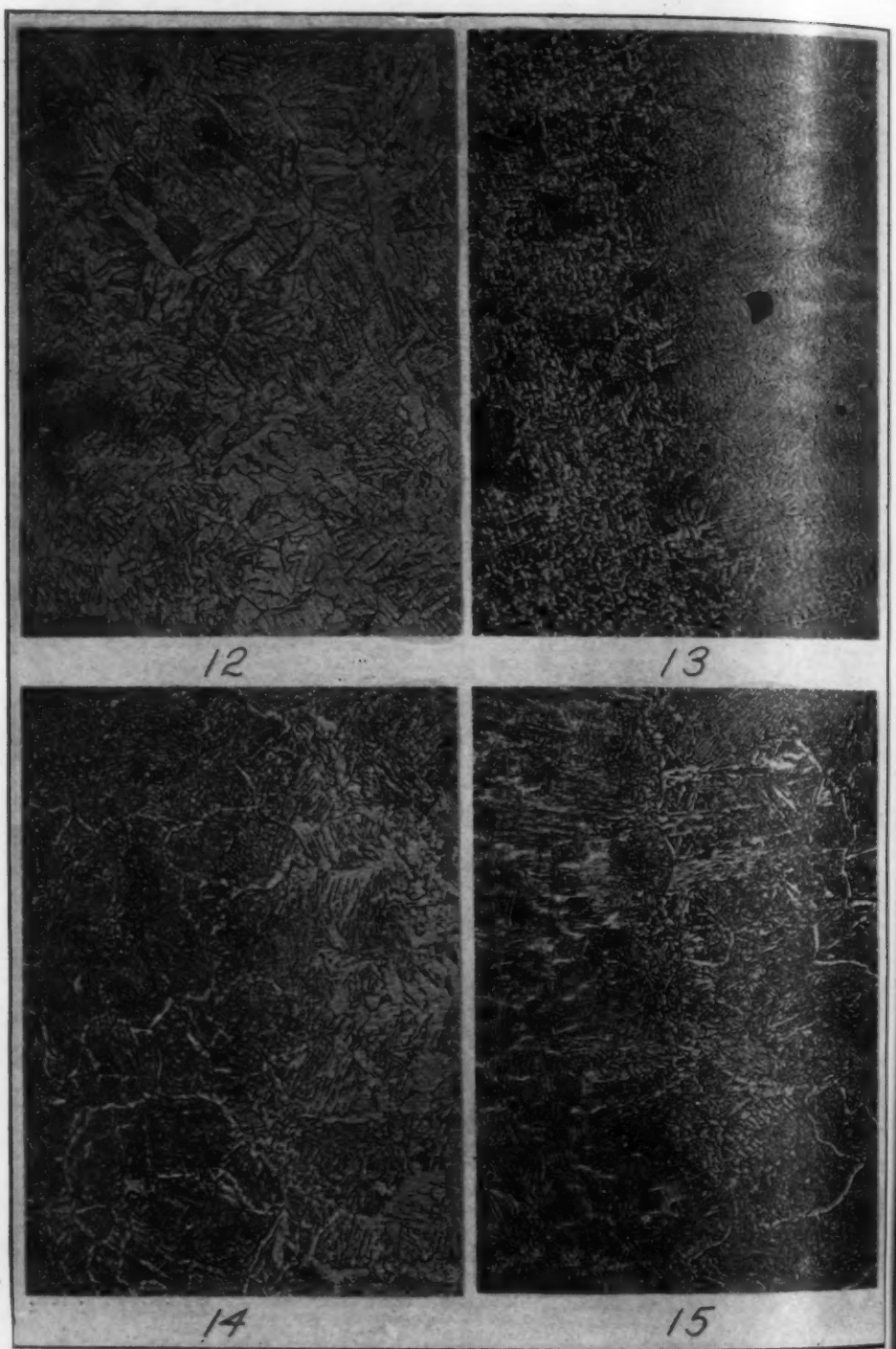


Fig. 12—Photomicrograph of the Structure at the Weld of a Low Carbon Steel Tube Welded with a Low Carbon Steel Welding Wire—Not Heat Treated. Fig. 13—Photomicrograph of the Structure at the Weld of a Low Carbon Steel Tube Welded with a Chromium-Molybdenum Steel Welding Wire—Not Heat Treated. Fig. 14—Photomicrograph of the Structure at the Weld of a Chromium-Vanadium Steel Sheet Welded with a Low Carbon Steel Welding Wire—Not Heat Treated. Fig. 15—Photomicrograph of the Structure at the Weld of a Chromium-Vanadium Steel Sheet Welded with a Chromium-Molybdenum Steel Welding Wire—Not Heat Treated. All Magnifications 100 X.

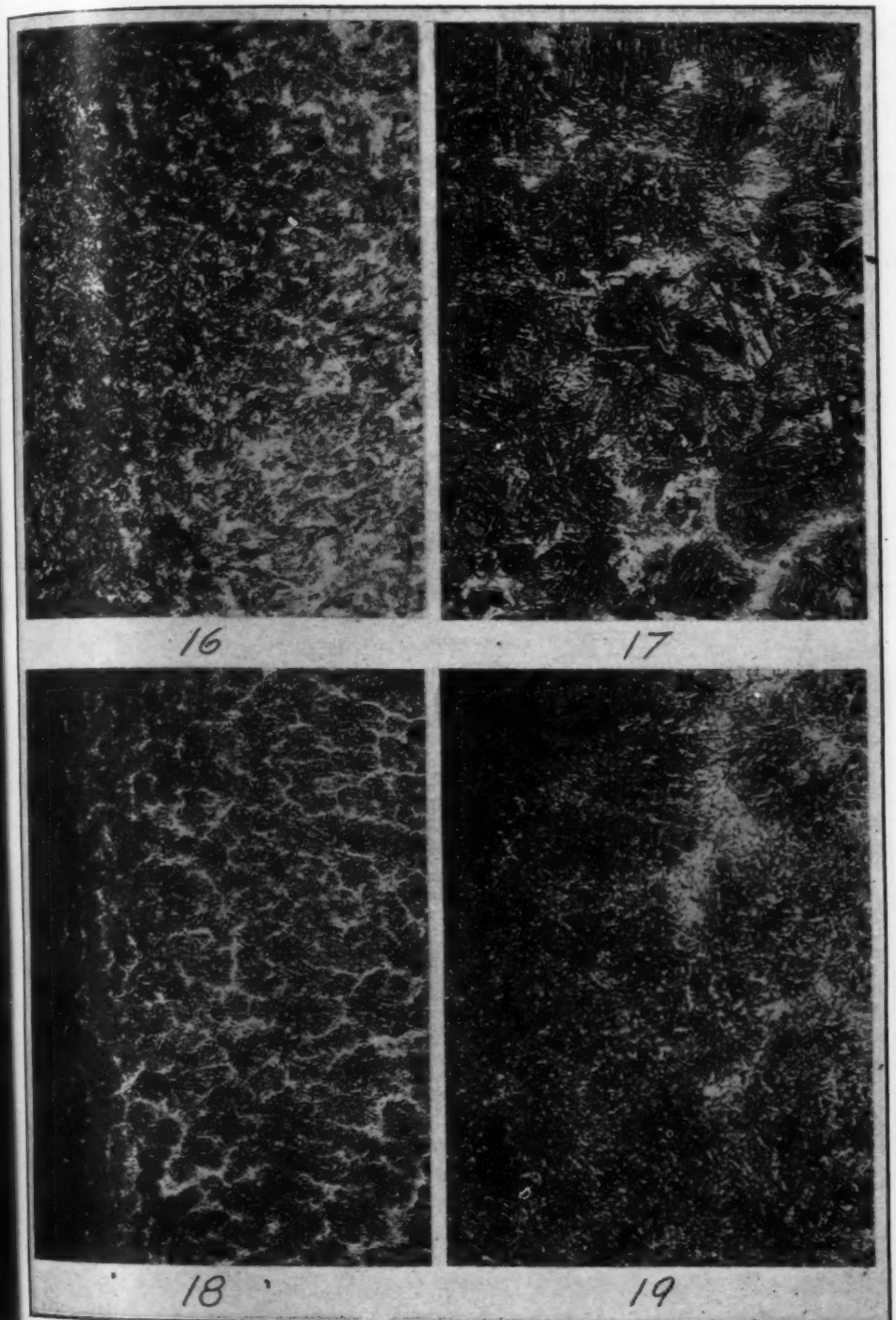


Fig. 16—Photomicrograph of the Structure of the Weld of a Chromium-Molybdenum Steel Tube Welded with a Chromium-Molybdenum Steel Welding Wire—Quenched in Water from 1625 Degrees Fahr.—Not Tempered. Magnification 100 X. Fig. 17—Same as Fig. 16, Magnification 500 X. Fig. 18—Photomicrograph of the Structure of the Weld of a Chromium-Molybdenum Steel Tube Welded with a Chromium-Molybdenum Steel Welding Wire—Quenched in Water from 1625 Degrees Fahr, Tempered at 800 Degrees Fahr. Fig. 19—Same as Fig. 18, Magnification 500 X.

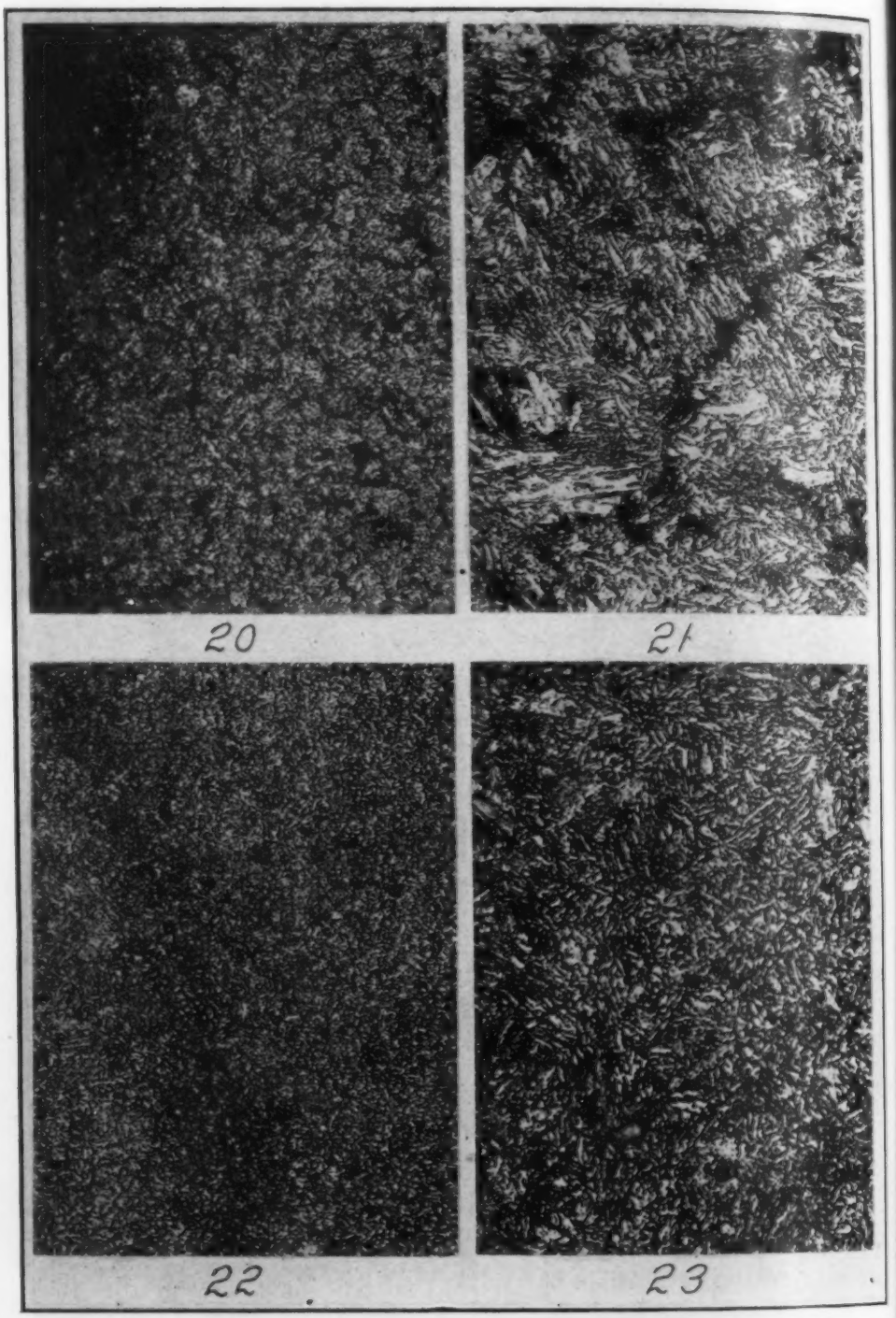


Fig. 20—Photomicrograph of the Structure of the Weld of a Chromium-Molybdenum Steel Tube Welded with a Chromium-Molybdenum Steel Welding Wire—Quenched in Water from 1625 Degrees Fahr., Tempered at 1250 Degrees Fahr. Fig. 21—Same as Fig. 20, Magnification 500 X. Fig. 22—Photomicrograph of the Structure of the Weld of a Chromium-Vanadium Steel Sheet Welded with a Chromium-Molybdenum Steel Welding Wire—Quenched in Water from 1625 Degrees Fahr., Tempered at 1000 Degrees Fahr. Fig. 23—Same as Fig. 22, Magnification 500 X.

chromium-vanadium steel sheet. With medium carbon steel tube both welding wires are about on a par and with low carbon steel tubes, the low carbon steel wire seems to produce the most uniform weld.

The chromium-molybdenum and chromium-vanadium steels used in the tubes and sheet are slightly air hardening, consequently, the structure of the tubes and sheet of these steels is mostly sorbitic at the welded end. The use of chromium-molybdenum steel welding wire produces a weld that is also sorbitic. It may be assumed that when both the material welded and the weld proper are fine-grained sorbite, the strength and ductility of the welded member will be greater than a weld between steel of sorbitic structure and a steel of almost pure ferrite. This holds only for strength and ductility, as there seems to be some doubt as to the ability of steel of sorbitic structure to resist fatigue. This will probably be made the subject of a future investigation.

Metallography of the Welded Tubes and Sheet (Heat Treated)

The structure of the weld between the chromium-molybdenum steel tube and chromium-molybdenum steel welding wire as quenched in water from 1625 degrees Fahr. is shown in Fig. 16, at 100 diameters, and, in Fig. 17, at 500 diameters. The junction between the tube and the weld has not been completely obliterated. The structure, however, is very fine-grained, more so than the same weld not heat treated (compare with Fig. 9). The difference in structure at the weld in Fig. 16 is probably due to the difference in composition between the tube which contained 0.23 per cent molybdenum and the welding wire which had 0.95 per cent molybdenum.

Figs. 18 and 20 (at 100 diameters) show the structure at the weld of the quenched tube after tempering at 800 and 1250 degrees Fahr., respectively. The structure shown in Fig. 20 is excellent as regards uniformity of structure and grain size. This structure indicates physical properties superior to the material as quenched or as quenched and tempered at 800 degrees Fahr. It will be seen from Table VI and from Fig. 2 that the strength, ductility, and character and location of the fracture are better, when considered together, when the quenched tube is tempered at temperatures exceeding 800 degres Fahr. Figs. 19 and 21 are the

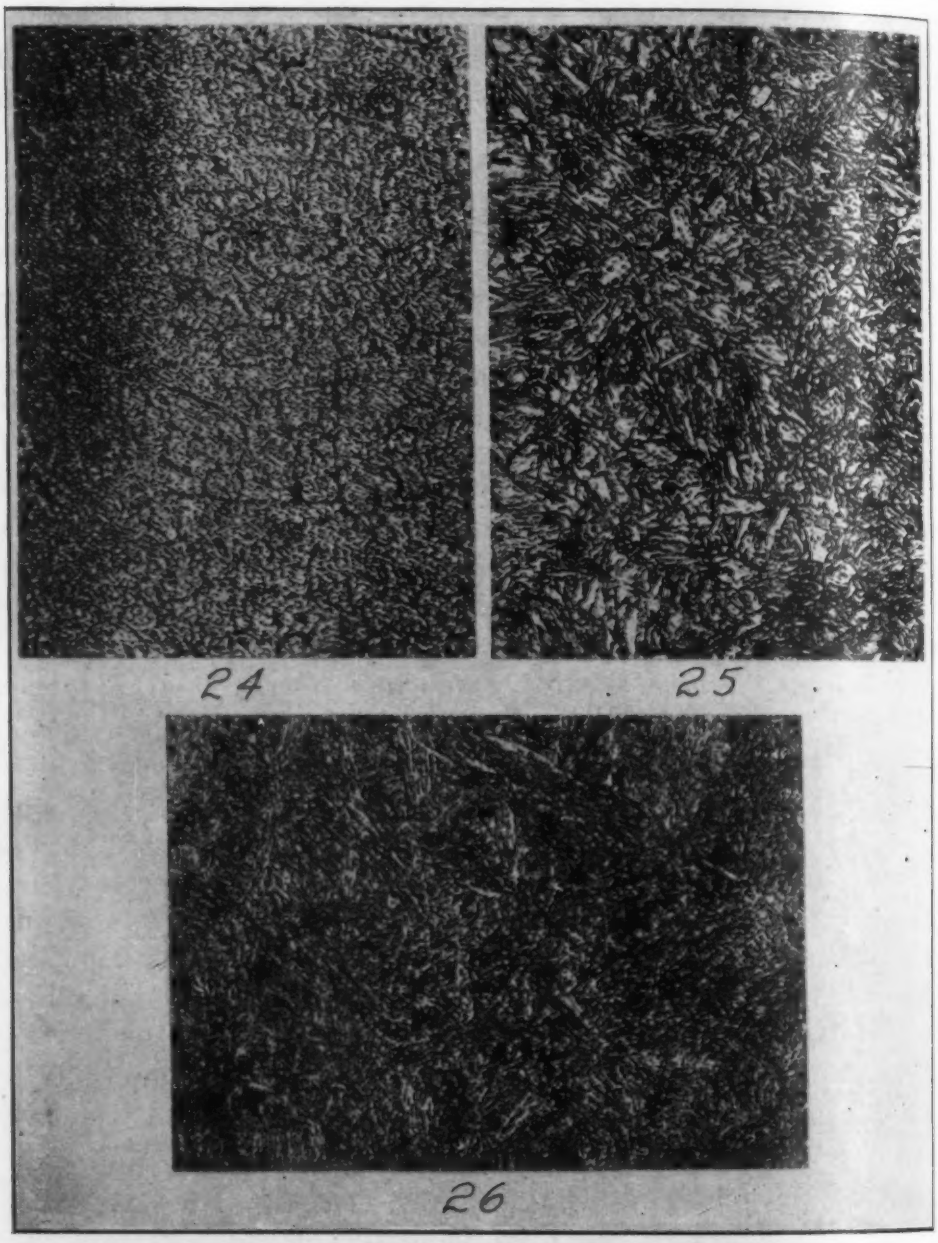


Fig. 24—Photomicrograph of the Structure of the Weld of a Chromium-Vanadium Steel Sheet Welded with a Chromium-Molybdenum Steel Welding Wire—Quenched in Water from 1625 Degrees Fahr., Tempered at 1250 Degrees Fahr. Magnification 100 X. Fig. 25—Same as Fig. 24, Magnification 500 X. Fig. 26—Photomicrograph of the Structure of a Chromium-Molybdenum Steel Tube Six Inches from the Weld—Quenched in Water from 1625 Degrees Fahr., Tempered at 1000 Degrees Fahr. Magnification 500 X.

same as Figs. 18 and 20, except that the magnification is 500 diameters.

Fig. 26, at 500 diameters, shows the structure of the chromium-molybdenum steel tube, quenched and tempered at 1000 degrees

Fahr., taken 6 inches from the weld. This photomicrograph is introduced to show the average structure of the material not affected by heating for welding. The structure is fine and no grain boundaries are evident. It probably consists of sorbite, together with small amounts of the transition constituents always present when a hardened steel is reheated for tempering.

Figs. 22 and 24 (at 100 diameters) show the weld between the chromium-vanadium steel sheet and the chromium-molybdenum steel welding wire after quenching in water from 1625 degrees Fahr. and tempering at 1000 and 1250 degrees Fahr., respectively. In both specimens, the grain size is small and fairly uniform. In the case of the welded chromium-vanadium steel sheet the junction at the weld is more sharply defined than in the chromium-molybdenum steel tubes. This is especially noticeable when tempered at 1250 degrees Fahr. (Fig. 24). This sharper line of demarcation at the weld may be responsible, in part, at least, for the fact that so many of the heat treated specimens fractured in tension through or near the weld (Fig. 3). The structure of the welds for these two tempering temperatures is shown in Fig. 23 and 25 at a higher magnification.

It is evident that the heat treatment has not been of as much benefit in the case of the chromium-vanadium steel sheet as it has in the case of the chromium-molybdenum steel tubes. In fact, the structure of the welded and heat treated chromium-vanadium steel sheet is not as good as the structure of the weld, not heat treated (compare Figs. 22 and 24 with Fig. 15). Heat treatment, however, has undoubtedly had the effect of equalizing the grain structure in the vicinity of the weld and of eliminating any soft area that may be present due to localized annealing in welding.

Conclusions

In welding seamless steel tube and sheet with chromium-molybdenum steel welding wire, it was noticed that wire of this composition is more difficult to work than ordinary low carbon steel welding wire. It flows less easily and does not flow uniformly through the junction of the two pieces to be welded and, consequently, does not form a uniform weld on the under side of the piece, as is characteristic of low carbon steel welding wire in the welding of thin sections. Welds made with chromium-molyb-

denum steel wire may be made as perfect, however, as welds with low carbon steel wire.

The physical properties of the various welded tubes and the sheet (not heat treated) are satisfactory and, as a whole, uniform. Failure in tension always occurs at the weakest spot which, in every case, was some distance from the weld. In the welded chromium-molybdenum tubing, a localized annealing took place about ¾ inch from the weld. With this material failure always occurred in this soft spot.

As regards the metallographic structure of the untreated welds, the most uniform and fine grained structure resulted from welding chromium-molybdenum steel tubing with chromium-molybdenum steel welding wire. Welding chromium-vanadium steel sheet with this wire also produced an excellent structure. In welding chromium-molybdenum steel tubing to medium carbon steel tubing, chromium-molybdenum steel wire apparently is but little better than low carbon steel wire, and in the case of a low carbon steel tube the structure of the weld with chromium-molybdenum steel wire is no better, and, perhaps, even inferior to the weld with low carbon steel wire.

Heat treatment of the welded chromium-molybdenum steel tubes and chromium-vanadium steel sheet has served to eliminate the soft area present near the weld in the untreated tubes and in general has served to equalize the structure at the weld and produce a fine grained uniform material. The best structure, and physical properties, as well, result from a tempering temperature of 1000 degrees Fahr. and above. Heat treatment, however, has not obliterated the junction of the tube or sheet and the welding metal. Probably a still better structure would result from normalizing, followed by quenching and tempering.

The effect of heat treatment is not so important in its improvement of physical properties as in the refinement and equalization of the structure at the weld, although quenching followed by a high tempering temperature improves the ultimate strength and elongation sufficiently to make it advisable to heat treat all welded chromium-molybdenum steel tubes and chromium-vanadium steel sheet, if possible.

An adverse factor entering into heat treatment of thin welded sections, such as tube and sheet, is the probability of the piece warping in quenching. For this reason, a simple normalizing

treatment would probably be sufficient, except in the case of highly stressed members.

The authors wish to acknowledge their indebtedness to J. L. Hester, who made the photomicrographs included in this paper.

Written Discussion:—By S. W. Miller, Union Carbide and Carbon Research Laboratory, Long Island City, N. Y.

There is a constant endeavor in the case of aircraft to reduce weight, and any process that will enable this to be done safely is of great value. The work as outlined in this paper is in this direction, and the results indicate quite clearly that considerable success has been attained by the use of fusion welding. There are several points that might be commented on.

It is stated on page 3 that it was desired to have the welding rod of the same composition as the tubing. It has been found that molybdenum in a chromium-molybdenum welding rod, over 0.35 per cent, is not only of no advantage, but actually gives bad welding qualities, the metal being difficult to melt because of the heavy infusible slag on the surface. Otherwise, the composition of the welding rod used should be quite satisfactory as far as welding qualities are concerned, if the silicon content, which is not given, was about 0.40 per cent. It might also be said that molybdenum seems to increase the ductility of the metal by dispersing the carbides and that only a small amount of molybdenum is needed—just enough to prevent the formation of lamellar pearlite. It seems also to be true that slow cooling makes molybdenum steel somewhat coarse grained, so that again a small amount only is advisable. These and other facts in connection with chromium-molybdenum welding rods have been found during an extensive study that resulted in a patent being recently issued to F. M. Becket that covers the desirable chromium-molybdenum welding alloys.

It should be pointed out, also, that any welding wire that works with difficulty because of the formation of heavy infusible slags on the surface of the weld, works much better in the bottom of the V, or when using it for welding thin metal, than when it is used, for instance, in ½ inch plate, and so with thicker metal high molybdenum content is particularly objectionable.

It is well to observe caution in using any figures in the physical properties of welding wire, as they have no relation whatever to the physical properties of the weld, because the welding wire has received both hot and cold work, while the weld metal is in an unworked condition. The idea has been in the minds of some that high strength welding wire necessarily produces high strength welds, which is often far from the truth. The weld being in the unworked condition makes it advisable to consider whether its heat treatment temperatures are the same as those of the base metal. Usually they are not, and better results can be obtained in such cases by using a special treatment for the weld. This is particularly advisable where the weld cannot be reenforced much or at all.

The breakage of two of the heat treated pieces in the weld raises the

question as to why they broke. It seems to the writer that this is of considerable importance. The exact line and nature of the fracture should be determined, that is, whether it was inter or intragranular, whether the weld was defective in any way, and, if possible, whether there was any injury due to the heat treatment. It may be that in these two cases the welding procedure control was different from those in the other cases. While the physical properties seem to have been equal to those of other welded tubes, breaking in the weld where the section is so much larger than that of the tube, indicates that under service conditions vibration and other stresses that are not purely tensile might cause failure. It is possible that these were the first tubes welded and that more experience eliminated the welding difficulty, but the cause of failure should be determined.

There are two reasons for testing welded pieces:

1. To determine if the whole structure is strong enough
2. To determine the quality of the material in the weld.

The former was the object aimed at in this case, but it would have been interesting and instructive to have removed the excess metal from the weld by grinding to determine the strength of the weld metal if rupture occurred in the weld, and to determine the effect of heat treatment on the weld metal. The writer considers that this method of test is of much importance in all cases, and especially in a case as vital as this one, so that if it is necessary to use unreenforced or untreated welds, they may be properly designed.

A number of the fractures in the chormium-vanadium steel test pieces occurred in the welds, so that the results of the tests on these pieces are stated to be erratic. Here again the writer believes that these welds could with advantage be examined very carefully, particularly for the presence of intergranular films of oxide in the weld, or for evidences of rejection to the high temperature grain boundaries of any dirt in the steel itself. When the latter occurs it is within a very narrow zone, about 0.01 inch wide, next to the weld line. This result is in the writer's belief due to the solution of whatever impurities there may be in the steel in the narrow zone referred to when it is either fused or very close to the fusion point, and the customary rejection of the dirt to the high temperature grain boundaries on cooling. It is very noticeable in poor quality steel of low carbon content because the grain boundaries are outlined by ferrite, against which the particles of rejected dirt show up very clearly. In the case of fine grained sorbitic structures, the observing of the dirt would be more difficult and more care would be required to find it. It might be remembered that this defect gives a characteristic fracture in welds in plate, in that the rupture is parallel to the plane of the V and silky in appearance.

It has been the writer's experience that the use of vanadium steel welding rod produces a weld that before heat treating is exceedingly brittle. The reason for this he is not at all sure of and believes it useless to speculate without further tests. It is suggested, however, that the welding of any

(Discussion Continued on Page 665.)

EFFECT OF THE WORLD WAR ON THE IRON AND STEEL BUSINESS

By Sir Arthur Balfour

Abstract

This paper touches briefly on the historical aspects of the iron and steel business. It then proceeds with a discussion of more modern steel working practices and deals especially with the economic and financial factors both in Europe and America.

The author has pointed out that there is an enormous latent capacity for the production of steel the amount of which cannot be accurately determined.

A rather free and open discussion of international affairs constitute the later part of the paper.

I RECENTLY had occasion to look back into the history of the iron and steel trade and came across some very interesting information which I think perhaps you would like to have. The first indication that we have of metallurgy was Tubal-Cain who speaks about extracting iron from iron ore. How it was done in those days nobody knows. We do know that the Assyrians did carry on many metallurgical processes; and that hardening and tempering was quite well known to the Greeks.

Pliny speaks about large masses of ore being found in Spain, Elba and Assyria. That ore is still being worked today. He also makes this very interesting statement: "The quality of steel much depends upon the nature of the water used to harden it, and oil is preferable for small tools."

Of course, it was the Romans who really spread the art of using iron and steel to any great extent over the face of the earth. Their first forges were merely excavations on the windward side of a hill. They afterwards began to line them with clay, which is, no doubt, where we obtained our idea of fire brick lining. And then their difficulties of the blowing machine came. The first single valve bellows was made by the Romans in the 4th century. And then in 1640 they produced a method which was called the "trompe" method of producing air blast by throwing masses of

A paper presented before the Cleveland Chapter of the Society, September, 1925. The author, Sir Arthur Balfour, K. B. E., is president of the Arthur Balfour Steel Co, Sheffield, England..

water down a long tube. In 1760 the first cylinder blowing machine was produced.

In my own woods in Sussex today I find heaps of what apparently is grass. If one walks on those heaps he can hear a grinding noise underneath. If he digs down he can find the old slag heaps from the time when they made cannon in Sussex. This slag is in exactly the same condition as it was then. It has not changed in the slightest degree. The grass has managed to find enough earth to grow on the top of it.

In 1735 coke was first used by Abraham Darby in Coldbrook. That is the first record of the use of coke for smelting purposes.

Of course, the Watt's steam engine then came on and created a great industrial revolution in every direction. But the puddling forge, curiously enough, was not invented until 1784.

Then I came across a very interesting thing. The son of the original Huntsman who manufactured crucible steel, gave me a small pamphlet. I have it still, locked away in my safe. This pamphlet was printed by his friends because they thought that he was not getting sufficient credit for the production of crucible steel. It is very quaint. The whole idea of it was to try and give him credit and push his production of crucible steel. Curiously enough, Huntsman never developed crucible steel to the extent that it has been developed in England by many companies and in this country afterwards. He always maintained quite a small plant. That plant is in existence today, although not on the same site.

Well, then, of course, we come into modern times with which you are all perfectly familiar—Bessemer steels, high speed steels, stainless steels, etc. I think the great revolution which has affected all of those in this room, I presume, who treat steel and perhaps many outside, is the question of the introduction of alloys. That has totally revolutionized the whole question.

And the amount of alloys that the steel will absorb is something like the problem of how much Scotch whiskey a Scotchman can absorb. I am told that the Scotchman can absorb any *given* quantity.

You have perhaps developed and been responsible for developing in this country the microscopic-examination of steel—the analysis of steel to an extent that is perhaps not being done in any other country. The foundation of it, no doubt, was laid in England

and France, and Europe generally, but you are to be congratulated on the immense advances that you have made. I have recently been through some of the big works here and I have been very much impressed, indeed, with the progress that has been made in the last five years, and the extraordinary efficiency with which your furnaces are run and your heats are controlled for all classes of treatment.

I think that Professor Arnold of Sheffield, no doubt, was one of the greatest metallurgists and did a great deal to advance the cause of metallurgy and heat treatment. He tells the story I am going to tell you about himself, so it is perfectly all right.

He had been lecturing at Sheffield University one day. (He had a reputation of being a little proud of his knowledge of steel, etc.). And he went out to a little village outside of Sheffield where he lived, and was walking up the hill to his home and overtook a miner who was very drunk. And this miner looked at him and said, "Professor, you think you are the cleverest man in the world."

"Oh! no," said Arnold, "I do not—I do not think anything of the kind."

"Oh! yes, you do. We all know that is what you think about yourself. Well, I'll tell you something. I know something you do not know."

So Arnold said to him, "Well, what is that?"

"I will tell you, I am wearing your shirt."

So Prof. Arnold said, "That is nonsense; that can not be the case."

"Oh! yes, I am. My Missus takes in your washing." (Laughter.)

Now I think in our country—I do not know so much about yours—there is very grave danger of losing sight of the practical man, the man who forges the steel, the man who handles the steel in the rolling mill, the man who handles it all through the processes up until the time it comes into the works to be made into tools. I do hope that with all of the scientific arrangements we now have, we shall not lose the skill of the old practical forge man, the old practical roller and steel melter, which was very great, indeed, and which we ought to find some means of retaining.

I find one of the gravest difficulties in a works of my own type is to get the theoretical man to work with the practical man. I think that it is very much to the detriment of both when they do

not work together. However, I think that is a thing to which we have got to gravely turn our attention in the future if we want the skill in the treatment of steel to advance along general lines and not to get on to one scientific line alone.

I believe that the original melting of the steel is of the highest importance. We had old melters in our works who could tell you by the way a steel melted whether there had been any change in the process of making the iron which they were melting. They had the feel of the thing. They knew exactly what was happening in the crucible. These men are of very great value indeed, and I hope that this class of skill will not be buried and lost by too much scientific skill.

Now to turn to the financial side of it. In Europe today there is over one thousand million pounds of international trade not being done. That, of course, is very gravely and deeply affecting the iron and steel trade of Europe. We have also (due to the war) had placed on the shoulders of the iron and steel trade in Europe, and in England particularly, very grave social cost burdens. Take the instance of the crucible steel industry. Before the war, what we called "social services" imposed by the state—that is, health insurance and acts of that kind—amounted to about one pound per ton of steel produced. Today, the same services, with some additions to them, amount to nearly five pounds ten per ton of steel produced. That is a very big burden, indeed, and one that is not very easily gotten rid of. This condition applies throughout the production of steel in the British Isles, even into the heavier trades where it is, of course, in different proportion. We have to seriously consider in Great Britain whether we have not overdone the spending of money on social services and thereby strained the cost of production.

We are spending in Great Britain four hundred million pounds per annum in general social services—that is, government services—whereas our whole governmental income, pre-war, was only two hundred million pounds. We have to raise another four hundred forty million pounds to run the country in addition. Those are figures which are very substantial when you recall that they are placed on the shoulders of about 45,000,000 people, and they are seriously affecting our cost of production today.

But we have another factor with which we have to deal. We have been burdened in Great Britain by a great many national

settlements—national settlements of wages in the steel trade, in the railways, and in the colleries. And these national settlements have made the production of steel very difficult, indeed. For example, we are paying a man who watches a crossing in Scotland where there are two or three trains a day, the same sum as the man who watches one in London where there are thousands of trains a day. Well, that kind of national settlement of wages, I hope, is something you will try and keep away from in this country, because it is an impossible problem. It is a very nice way of trying to settle your business, to settle one wage in one place and not to have the personal worry of looking after it. Sooner or later, we in England will have to come back to sectional settlements in the iron and steel trade and other trades belonging to it, such as transport and coal, if we are to successfully produce in competition with you and other countries of the world. Of course, the very big change-over has been the German and French situation. Most of you in this room know the situation very well.

The French took over the Alsace-Lorraine works, but the Germans retained the coke production. England was never in a position to supply adequate coke to France to run those furnaces; even had we had the coke to spare, there was no means of transporting the volume needed, and sooner or later some arrangement between the Germans and the French, antagonistic as they were, was bound to come. That arrangement has now come about and they have made an arrangement for exchanging ore for coke. This has altered the whole balance of export trade of the world, and the French suddenly find themselves with 5,000,000 tons of steel to dispose of, which they never had before. I am not sure that from the international point of view that the French are not easier to compete with than the Germans. The difficulty is that all of the works throughout all of the countries of the world have enormously increased their output. We have one works in England where they put up twenty-eight 50-ton furnaces. They never ran them. They were finished and completed, but they never ran more than five or them. So the grave danger in the iron and steel trade of the world is that there is an enormous latent capacity to the extent of which nobody knows, because it has never been tested. This is shown by some figures which I can give you.

Take the pig iron capacity of the six leading countries—that is, the United States, England, France, Luxemburg, Germany and

Belgium. It is 93,700,000 tons. Of that you in the United States can produce 52,000,000 tons; Great Britain, 12,000,000 tons. Then comes Germany with 12,000,000 tons and France with 11,000,000 tons, which is now slightly increased.

The steel ingots and casting capacity of the world today is 100,000,000 tons. Well, those of us who have been connected with the iron and steel industry know that 100,000,000 tons takes a bit of selling and a bit of getting rid of. The difficulty is that there is a big volume of trade being done in the world today on much too fine a price. It is not leaving enough margin to cover the risk and the strain of carrying stocks and carrying on experimental work and maintenance of buildings.

The pig iron production of Great Britain in 1924 was only 7,000,000 tons, compared with its possible production of 12,000,000 tons. You in the United States were somewhat more fortunate. You produced 31,000,000 tons as against 52,000,000 tons, your capacity. You were up to 60 per cent of capacity and we were up to 58 per cent of our capacity. And when we come to the steel castings and ingot side, we find we produced 64 per cent of our capacity and you produced 82 per cent of capacity. So that you have made greater strides than we have.

And, of course, we have very grave aftermaths of the war to face, not least of which was the question of Allied debts. The amount of debts owing to Great Britain by the Allies today is still two thousand million pounds sterling. The interest on that alone at five per cent is one hundred million pounds. And that one hundred million pounds is being borne by the British taxpayer, instead of being spread over Italy, France, Belgium and other countries. And curiously enough, the only country that is paying its debt—war debt—to Great Britain is the little country of Poland. They have made several payments and are maintaining them steadily.

But you can see that is a very grave burden under which we are suffering. Our taxation today in the highest category is 12 shillings in the pound sterling. That is 60 per cent of the income. And, of course, that very seriously reflects on the production of steel. Another very great handicap which we have is what we know as our *sheltered trade* difficulty. During the war the municipal employe—the tramway worker, gas worker or electric station worker for the city governments—obtained very much higher

wages on account of the cost of living. Those wages have never gone down in any proportion to the fall of the cost of living. And we have the extraordinary situation today of a tramway worker or a man who works in cleaning the streets, receiving 60 to 65 shillings a week, whereas a skilled engineer or a skilled steel worker in only getting 48 or 50 shillings. Naturally, we have a very grave problem between sheltered and unsheltered trades. The bulk of the steel workers and the engineers are dependent largely on export trade.

The competition is coming in our case, and I think also to the extent that you do the export trade of the world, from the Belgians. We find that the Belgians today can produce steel cheaper than anybody else in the world. This is also true of Alsace-Lorraine, the De Wendel Works, and works of that kind. However, I think we must not lose sight of the fact that they always did produce cheaper steel than anybody else in the world, and therefore the competition is not new but rather exaggerated at the present time, by the fact that there is not enough to go around to fill the capacity of the world's steel production.

Competition is extraordinarily keen. You have competition in your own country, but we who have to live by our exports, as Great Britain does—when we have to import 82 per cent of our foodstuffs—we really are nearer the economic rocks than any other country in the world and we feel competition very keenly. It has produced some very extraordinary results. Perhaps you remember the story of the man in Chicago and the man in New York who started keeping chickens in competition with one another. They thought that they would keep very close accounts and see who could keep the chickens for the least money. For a long time the New York man was getting ahead of the Chicago man, but finally the Chicago man thought he had found a method of getting over that. He began to put sawdust in the meal that he gave his chickens. He kept putting in sawdust until he got about seven-eighths sawdust and one-eighth meal. The next time he met his New York friend he had an extraordinary account of the small amount it cost him to rear these chickens.

The New York friend said to him, "That is all very fine, but what happened when you came to hatching time?"

"That was the most extraordinary part of the business," said his Chicago friend. "We had one old hen who sat on 13 eggs,

and she hatched 12 of them. Eleven had a wooden leg apiece and the other one was a woodpecker."

Well, we have had some very extraordinary results in competition in steel making and in the production of alloy steels. The competition was never fiercer and never keener. I think what you must be feeling in this country is also what we feel, that the introduction of alloy steel has made the whole problem of steel production very much more difficult from the point of view of the scrap.

In the old days we either had a self-hardening steel or a carbon steel. We knew exactly where we were on the scrap situation Today all of us receive scrap from our customers; we all have to deal with scrap of so many different compositions that it is extraordinarily difficult and only an extraordinarily well organized works can keep them separate. When they have been kept separate it is still a very difficult task to make steel. One of the grave difficulties of the future is dealing with scrap of these enormously complicated and varying alloyed steels.

There is a great deal of discussion at the present time in Europe, and I dare say it has extended to this country also, as to the advisability of international agreements between steel makers of the world. Well, now, I personally am against international agreements. What is the object of an international agreement? It is generally to restrict output with an object of getting a better price. Now just at the moment when we are blaming the worker for restricting output through his trade unions, for trying what is called *canny* on our side—to do less work with the false idea that the less one man does the more work there is for another—at that time is the most inopportune time for big international arrangements, the object of which is to restrict output and the only final object or result of which can be to increase the price.

I believe the only salvation for the steel trade or any other trade is to get right down to it and produce as cheaply as possible, and to eliminate the inefficient, so that the largest number of people can use these products or the results of them. In that way, and that way only, shall we be able to face the worker when we complain to him that he is restricting output and interfering with the progress of the country.

Now, we also have a very grave difficulty which I am going to venture to speak to you about, and that is the question of

mixture patents. There have been mixture patents patented in this country which, if they were maintained and fully carried out as they are patented, would so much restrict the research work of metallurgists in steel that in many directions it would cut off research altogether. We see patents granted nowadays with very wide ranges of nickel and chromium, and I think it is time that great societies like your own talk this matter over, because we never want to be hindered by patents that restrict research and confine the area in which our chemists and our research men are working.

We also have this question constantly before us. As you know, there was a Washington eight-hour convention. The United States never ratified it. Great Britain has never ratified it. The French have, the Belgians have and the Germans have. But as soon as they ratified it they commenced and make local regulations. For instance, if Great Britain and the United States were to ratify the Washington convention we would stick to the eight-hour law and be tied by it. But the French today, although they have ratified it, 62 per cent of the workers are working nine hours or over.

I am personally very much against the ratification of an eight hour arrangement which would tie our hands as to the future. We are being pressed by the trade unions very much, indeed, in Great Britain to ratify this convention. And they have gone over to the continent and talked to the German and French workers and the Belgium workers, trying to persuade them to have a real eight hour day. And they have come back very much crestfallen lately.

You can take it from me that the Germans, particularly, are going to work as many hours as may be necessary to pull themselves out of their present difficulties. I do not think there is any doubt about it. They are people with great skill. They are people with great application. And they are going to work as many hours as may be necessary.

The Dawes plan, for which this country and General Dawes and Mr. Owen Young are very largely responsible, has been a Godsend in a way, because it has restricted the German competition. It has done away with inflation. And inflation is nothing more than taking people's money away in taxes in another form. And while they had this constant inflation their competition in the iron and steel trade was very severe. Now that they are back to a gold standard we in England find that their competition is on a normal

basis and is reasonable competition and is again going away from the fantastic competition which inflation brought about.

We have recently been making some very careful examinations in England as to the amount of cost of freight and transport in steel, and we have come to the conclusion that 26 per cent of the cost of producing steel is transport. We have also come to the conclusion, after very close analysis, that up to 90 per cent of the production cost of steel is labor; that is, labor in one form or another, from beginning to end. Therefore, we have certainly got to find means to try and reduce our labor cost which is constantly growing and put in more mechanical devices than we have used in the past. I think you are ahead of us in regard to that.

On this question of Allied debts again. One of the most extraordinary features of the Allied debt question is the fact that it has now been brought home to the whole world that large sums of money cannot be transferred from one country to another country unless there is a transfer of goods or services of an equivalent value.

The extraordinary thing about the settlement of the Treaty of Versailles, of the amount of reparations that Germany was to pay, was the total overlooking of the fact that while Germany was a great exporting country, and while German competition was very rampant and very much advertised and very noticeable, that they did import eighty-five million pounds sterling worth of goods more than they exported, and therefore they were a very big factor in the world's international trade, and a factor that was useful to you and to us in Great Britain. If that factor had been realized when the Treaty of Versailles was being discussed, I think, the whole arrangement would have been on a different basis, because it is going to be extraordinarily difficult for Germany without immense effort, without enormously lowering their standard of living and without working exorbitantly long hours, to pay very large sums for reparations quickly.

As you know, the Dawes' plan avoids that impasse to some extent, because the reparations are paid in gold marks into a bank in Germany, and the date of their transfer, or the manner in which they will be transferred is left to the future. Well, of course, it will take a very great many years to transfer that money. It must take a great number of years. And therefore, in any arrangement of Great Britain with France, or any other coun-

tries, we manufacturers in Great Britain are in favor of only moderate payments spreading over a great number of years.

I think one of the most extraordinary things happening in the financial world is the arrangement to which we have come that we are to pay you thirty-two million pounds sterling rising up to thirty-five million pounds sterling for 65 years. You may say that it would have been a fantastic scheme for any two nations to come to such an arrangement, because they would not have kept it, but here we Anglo-Saxons have calmly and without fuss come to an arrangement to pay you thirty-two million pounds and you know that we are going to pay, we know that we mean to pay it and shall pay it, and everybody is perfectly content to wait for that period of years. That in itself is a wonderful thing and one of the most marvelous things to happen in this century.

And even thirty-two million pounds has to be produced by goods or services.

You Americans have put up the Fordney tariff which has considerably restricted our opportunities of paying you that money. You have gone in for prohibition which restricts us from sending you as much Scotch whiskey as we would like to. All those things, of course, prevent us paying you the money as quickly as we should like to.

Recently I see that there has been some anxiety on the part of America about the price that we are charging for rubber. The price is perfectly natural when you consider we are paying you thirty-two million pounds per annum. It is a perfectly natural consequence. I see even that your Ambassador has been working overtime in London making complaints about the price of rubber. Well, I hope that the British Ambassador at Washington will not complain to your government about the price of wheat, meat or cotton because I think that all those questions of trade are very much better handled by the practical people who understand them and should be kept as far away as possible from the governmental control or governmental management.

I do not know whether it is appreciated throughout the world how important it is for the iron and steel trade that Great Britain has returned to the gold standard. I do not think we should have been able to return to the gold standard as quickly as we did unless the Federal Reserve Bank of the United States and the Bank of England had been very close friends and had come together and

helped one another. It was to your interest that we should return to the gold standard. You have the biggest mass of gold in the world. You have more than half the world's gold stored in this country, and therefore you want to maintain gold as a standard. It was to our interest to have a fixed basis on which to trade. It was also to our interest from another very important point, and that is the point I have already touched on, that we import 80 per cent of our foodstuffs. Whether we pay for that foodstuff in a depreciated currency or on a fixed gold basis makes an enormous difference in the cost of living and the happiness of the working people of Great Britain. But not only that. Nobody would have believed that Great Britain with the strain which she has carried could have returned to the gold standard so quickly. And the fact she has done so and faced all of the consequences—and mind you there are very grave consequences, such as the depression of prices and to writing down of stocks by very large sums—is to the credit of her people. It has been worth while, and we do very much appreciate the fact that the Federal Reserve Bank of this country and the Bank of England worked so closely together to bring it about.

What has been the immediate result? The immediate result has been that other countries who are a little bit nervous about the process are following Great Britain's lead and are already going back to the gold standard. And I am very pleased to be able to tell you that quite contrary to the anticipations of many people who were pessimistic, Great Britain has eight million and a half pounds more gold in her vaults than on the day we returned to the gold standard.

The other reason why it was important that we return to the gold standard was the question of credit. We cannot carry on the iron and steel trade of the world—international iron and steel trade—without free credit. One of the greatest hindrances in giving credit in the past has been the doubt as to the value of currency at some future date.

I believe that France will, now that she has been able to come to an arrangement as regards her debt to you and to us, turn her whole attention to following our lead and go back to the gold standard. Then Italy will follow and then the world will once more be in position to do international trade without the risk and

anxieties which have been on all of our shoulders during the past years.

I thought you might like to have some of the figures for the latest wages of German workers—that they would interest you. These are only of May of this year, so that they are pretty well up to date.

The skilled worker in the metal industry in Germany, pre-war, was getting 36.72 marks. In May, 1925, he was getting 41.26 marks. That is 114 as against 100. Unskilled workers were getting 23.79 pre-war, and in May, 1925, they were getting 28.13. Those are very low wages, but gradually the German worker is demanding higher and higher wages, as he finds on the gold basis he cannot live at these figures, and no doubt will have to receive them.

The progress of the United States is so phenomenal that very few people have grasped it. I have just been looking up some figures as to the real progress of the United States in the last 20 years; that is, not the last 20 years, but the 20 years ending in 1913—before the war. Your population increased by 46 per cent. Your acreage under corn increased by 47 per cent. Your coal output increased by 210 per cent; your pig iron production by 337 per cent; and last but not least, your steel production by 715 per cent. These are extraordinary and phenomenal figures, and I think the last figure does very great credit to the metallurgists of this country for the enormous amount of progress made in that short space of time.

But you have another great advantage of which we are rather jealous. That is your coal output. In 1883 you were producing 33 hundredweight of coal per man per day. At that date we were producing 25. In 1913, you produced 60 hundredweight and we 21. We were going back, you see. In 1923 you produced 80 hundredweight per man per day and we only 18. Now that is really our coal problem.

We have had this national wage settlement and this national union which has resulted in a reduction of output per man, but gradually the rank and file of Great Britain are coming home to the fact that if they want to have the high standard of living, if they want to have a high wage, they must produce. And I am glad to be able to tell you that there is a great educational work going on amongst the workers in Great Britain, and I think we are going

to see from now on—and we are already seeing it—an improvement of output per man per day.

Of course, a country whose national debt in 1914, like ours, was one thousand six hundred eighty million and in 1924 is seven thousand one hundred ten million sterling, has a very grave problem on their shoulders. But personally I am not worried about the national debt. I am perfectly satisfied that we can face it, we shall face it, we are facing it to the extent of fifty million sterling per annum, plus any surplus there is from our income. And last year we paid off eighty-five million, and if we continue to do that steadily it is a much better plan than dashing in and trying to remove that debt by any sudden measure, because that would do two things. It would upset confidence (the capital levy has been proposed but is not very much in favor now) and alter the security market of Great Britain. Today a great deal of that national debt is lying in the bankers' hands as security for over-drafts for industrial purposes. If we eliminated it we would upset the whole security basis of the iron and steel trade and we would create chaos. Therefore, I am strongly in favor of continuing on our present basis and paying off our debt gradually.

I think I have pretty well dealt with the situation—the international situation and the British situation. All I can say is that we are struggling through very, very difficult times in Great Britain. We are quite convinced we shall overcome them. And we are very grateful indeed for any help your Federal Reserve Bank can give us or you can give us in facing the very grave difficulties which have been thrown on 45,000,000 people by the great war.

There is no doubt if we had not stepped into the war when we did the French and Italians could not have stood the strain and we might have a totally different world position to face than we have today and Anglo-Saxons can be thankful that we went together and fought that menace.

I honestly believe that the only hope for the world in the future is a continued friendship of the United States and Great Britain. If we are going to have peace in this world it can only come about through our working together in the closest possible way, through our trusting one another through thick and thin, and allowing the great relationship which exists between us through emigration to work as it has worked in the past.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested To Refer to Serial Numbers of Questions

QUESTION No. 164. In the manufacture of cast iron pipe in a permanent mold, the pipe is removed from the mold at about 1200 degrees Fahr. and then reheated to about 1800 degrees Fahr. for an anneal. Are the structure and physical properties of this material any different from that of cast iron which has been allowed to cool to atmospheric temperature before being reheated to the 1800-degree Fahr. zone? Does anyone know where the practice of removing cast iron at red heat from a mold and reheating for "annealing" was carried out prior to 1918?

QUESTION NO. 163. What is the lowest temperature at which ingot iron or low carbon steel will carburize when packed with the usual type of commercial carburizer?

QUESTION NO. 162. To what extent will un-annealed cold drawn bar stock distort as a result of carburizing and hardening parts made therefrom?

ANWSER. By B. F. Shepherd, metallurgical department, Ingersoll-Rand Co., Phillipsburg, N. J.

Distortion is not only caused by the initial condition of the material, that is, whether cold drawn, hot-rolled, etc., but is also caused by all of the other factors which enter into the carburizing operation, that is, design of the part, carburizing practice, hardening practice, etc.

It is entirely improbable to predict with any degree of certainty the extent to which unannealed, cold drawn bar stock will distort as a result of carburizing and hardening. This operation is being carried out on a number of relatively unimportant parts made from this material at this plant, and we have practically no trouble due to distortion. Provided the design is not too complicated, I would say that very little trouble should be experienced with distortion of unannealed, cold drawn bar stock, providing PROPER CARBURIZING AND HARDENING PRACTICE is used.

QUESTION NO. 159. *What is the explanation for the retarding effect on corrosion of small amounts of copper in low carbon steel?*

QUESTION NO. 158. *What is the present recognized cause for the "transverse fissure" as occasionally found in rails?*

QUESTION NO. 157. *Does 0.070 to 0.090 per cent phosphorus in low carbon basic open hearth steel tend to prevent "stickers" in the rolling of sheets? If so, what is the explanation for such a tendency?*

QUESTION NO. 156. *What is the cause of "stickers" in the rolling of sheets from low carbon, basic open hearth steel sheet bar?*

QUESTION NO. 155. *Is it more advisable to cool an ingot from melting temperature down to room temperature before reheating for forging or to cool it down to 1000 degrees Fahr. and then reheat to forging temperature?*

QUESTION NO. 154. *What are the advantages of nickel steel versus chromium-nickel steel for carburizing?*

QUESTION NO. 152. *Is manganese up to 1.50 per cent detrimental in a steel to be used for carburizing purposes? How does the high manganese content affect the final product?*

ANSWER. By B. F. Shepherd, metallurgical department, Ingersoll-Rand Co., Phillipsburg, N. J.

Manganese in quantities of 1.50 per cent will render a carburizing steel oil hardening; consequently any attempt to quench these steels in water will result in spalling and the belief that the steel is brittle. Quenching in oil will give a very satisfactory product, providing the steel is initially satisfactory. Much of the early prejudice against high manganese resulted from some such hardening practice.

QUESTION NO. 151. *What effect does the temperature of an oil-quenching bath have upon the hardness of a piece of steel quenched into it from the proper hardening temperature?*

ANSWER. By H. J. French and O. Z. Klopsch, metallurgical division, Bureau of Standards, Washington, D. C.

Whether or not changes in temperature of an oil quenching bath will produce appreciable changes in the hardness of the steel quenched will depend upon the temperature variations considered, the oil itself, and other factors. Compared to water and aqueous quenching solutions, most oils which are used for hardening steels show very small changes with temperature in those cooling rates which largely control hardness in carbon steels. If the cooling rate at about 1325 degrees Fahr. is accepted as a criterion of hardness produced in quenching, then it may be said that for ordinary quenching oils and others including cottonseed, sperm, some mineral and most proprietary quenching oils temperature variations between 70 and 200 degrees Fahr. will not appreciably change the surface or center hardness produced in moderate sized sections of carbon steels. In many cases, the permissible variations in temperature are wider than that noted; on the other hand, some oils show real changes in cooling properties with comparatively small variations in temperature of the bath.

In the above comments, the term, hardness, refers to Brinell, Rockwell and Shore values. It should be noted that temperature variations in an oil bath which do not appreciably affect such hardness values may have a marked effect on the general properties of the steel quenched such as for example,

dimensional changes, stress distribution, permanence, cutting ability, magnetic properties, etc.

ANSWER. By B. F. Shepherd, metallurgical department, Ingersoll-Rand Co., Phillipsburg, N. J.

This question is answered very effectively in the publications of the E. F. Houghton Co. which have been corroborated in many cases by the writer's personal experiences. The effect of the temperature of the oil quenching bath upon the hardness of the steel depends entirely upon the quenching characteristics of the oil. Some oils will impart the same hardness to the steel at a bath temperature of 250 degrees Fahr. as at atmospheric temperatures. Others will increase the cooling rate and consequently hardness over that obtained at atmospheric temperature in the same oil. It must be remembered that the cooling speed is responsible for the hardness of the steel, and different oils have entirely different quenching speeds at the same temperature. Comparisons as to the effect of the temperature of the oil quenching bath must be made on the same oil.

QUESTION NO. 149. ***Do plates of basic open hearth steel ever have a higher base rate than acid open hearth steel?***

QUESTION NO. 142. ***What is the consensus of opinion of the cause of blisters in low and high grade steels sheets?***

QUESTION NO. 143. ***How can these blisters be eliminated?***

QUESTION NO. 138. ***Is the electrolytic pickling process being used to show up defects in steel bars? If so, how does it compare with the regular pickling processes?***

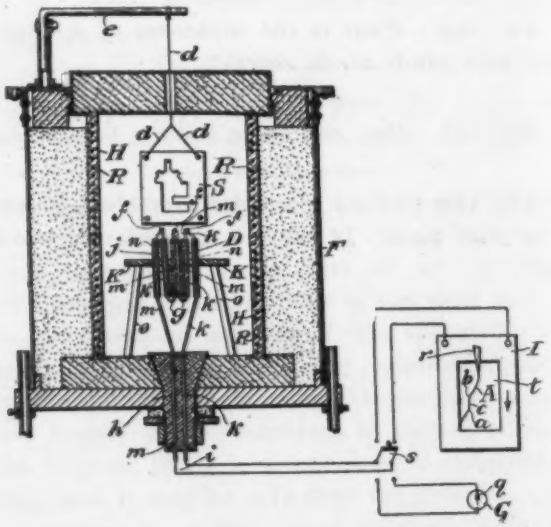
Reviews of Recent Patents

By
NELSON LITTELL, Patent Attorney
110 E. 42nd St., New York City
Member of A. S. S. T.

1,550,272, Method of and Apparatus for Heat Treatment, Charles A. **Martin, of Chicago, Illinois, assignor to Leeds and Northrup** Company, of **Philadelphia, Pennsylvania, a corporation of Pennsylvania.**

This patent relates to a means for accentuating the indication of the rate of change, for example, the rate of change of heat absorption or of heat dissipation in materials undergoing heat treatment so as to more clearly and unmistakably show when these materials pass through the critical transformation points.

The apparatus comprises a heat treating furnace H, heated by means of resistance wires R, in which the material to be heat treated, in the



present drawings a die S, may be suspended. Located inside the furnace at spaced points adjacent the material undergoing the heat treatment, are a plurality of thermocouples k having hot junctions f located adjacent the material undergoing the heat treatment and cold junctions located at a point removed from the hot junctions whereby to subject the same to a temperature differential. The effects of the separate thermocouples are combined into a joint effect by the deflection of the galvanometer G or by the automatic recorder I and by combining the indications from various points a more pronounced break in the rise or fall of the temperature time curve is produced.

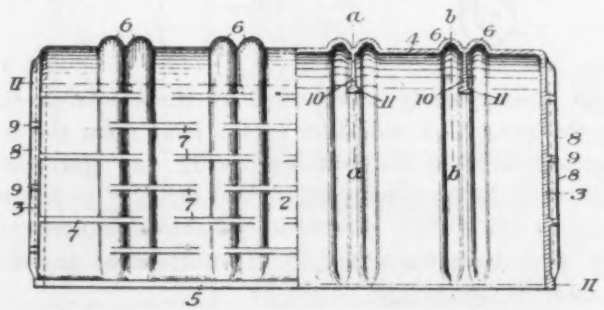
1,550,489, Heat-Treated Zirconium Steel and Process of Making Same, Frederick M. Becket and Alexander L. Feild, of New York City, assignors to Electro Metallurgical Company, a corporation of West Virginia.

This patent describes the method of heat treating ordinary carbon steel having a small percentage of zirconium therein, whereby a product is obtained having substantially the properties of a heat treated alloy steel. Zirconium in amounts from 0.04 to 0.40 per cent is added to ordinary carbon steel and when said steel is tempered, especially in the lower ranges of drawing temperatures, 350 to 450 degrees Cent., a marked improvement is shown, especially in the tendency to maintain the ductility of the steel, even when tempered under conditions which secure great hardness and high strength. The table shown below indicates the comparative tests of the properties in the zirconium-treated steel as compared with plain carbon steel and with an alloy steel.

	0.70% carbon 0.15% zirconium	0.70% carbon without zirconium	S. A. E. 3450. (Nickel-chromium)
	I	II	III
Drawing temperature	412°C.	412°C.	427°C.
Per cent elongation	12.7	7.5	12.5
Per cent reduction of area	45.8	22.9	51.0
Yield point, lbs. sq. in.	172,620	180,180	175,000
Ultimate strength, lbs. sq. in.	198,828	207,144	200,000
Izod number, ft.-lbs.	14.8	10.5	.....
Brinell hardness	407	418	.....

1,552,096, Annealing Box, William E. Troutman, of Pittsburgh, Pennsylvania, assignor to Duquesne Steel Foundry Company, of Pittsburgh, Pennsylvania, a corporation of Pennsylvania.

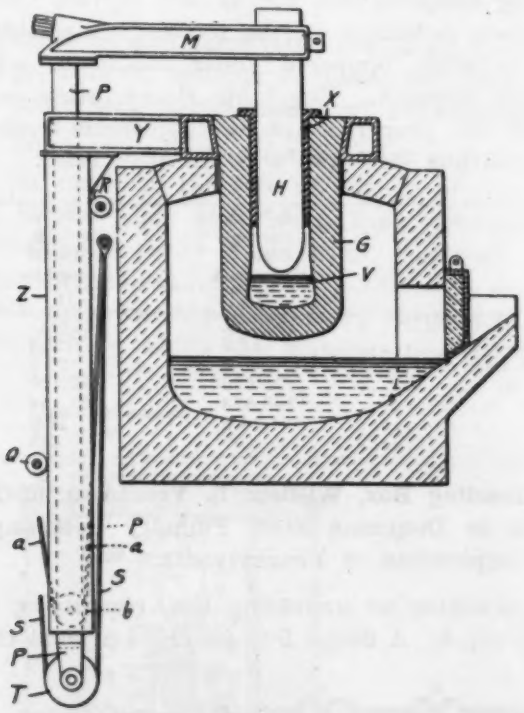
This patent describes an annealing box, comprising the side walls 2, end walls 3 and a top 4. A flange 5 is provided around the rim of the box



and corrugations 6 in pairs extend from the flange on one side over the top to the flange on the other side, the depression between the two corrugations being in the plane of the adjacent side walls. Ribs 7 extend alternately from each side of the corrugations 6 and overlap at the ends thereof, so as to provide a complete reinforcement of the box, and a truss 10 having a flange 11 at the bttom thereof, extends from the depression between the corrugations 6 across the arched top of the box and joins the side walls below top. The box is designed to be of very rigid construction, which will not warp, crack or distort under the severe treatment it receives.

1,552,143, Melting Low Volatile Metals and Smelting Ores Thereof, James H. Gray, of New York City.

This patent describes an electric furnace for melting low volatile metals, such as tin, brass or zinc. The furnace comprises a crucible provided with the usual pouring nozzle, into the top of which projects the hollow electrode G, which is closed at the bottom, and the rod electrode H projecting into the hollow electrode G. The arc is struck between the electrode G and



electrode H and is completely surrounded by the electrode G, which shields the bath from the arc. The radiation of the heat from the hollow electrode effects the desired melting without volatizing any part of the metal, as would be the case if the bath were subjected directly to the arc. To reduce the consumption of the hollow electrode, a bath of molten pig iron V, covered with slag, may be maintained in the bottom of the hollow electrode and renewed as it is consumed.

1,552,867, Hatchet Head and Process of Heat Treating It and Other Articles, George G. Mitchell, of Union, New Jersey, assignor to L. A. Sayre and Co., a corporation of New Jersey.

This patent relates to a method of heat treating hatchet heads and similar articles wherein it is desired to have a hardened head portion, a tough eye, and a properly tempered cutting edge.

The process comprises heating the entire article to a hardening temperature, quenching, heating the head of the article to a hardening tem-

perature, and temper drawing the intermediate or eye-portion and quenching only the head portion, by permitting a jet of water to play upon the head as it is immersed in the quenching bath.

1,552,848, Method of Increasing the Strength of Hollow Metal Articles, Frederick C. Langenberg, of Cambridge, Massachusetts, assignor of One-Half to Tracy C. Dickson, of Watertown, Massachusetts.

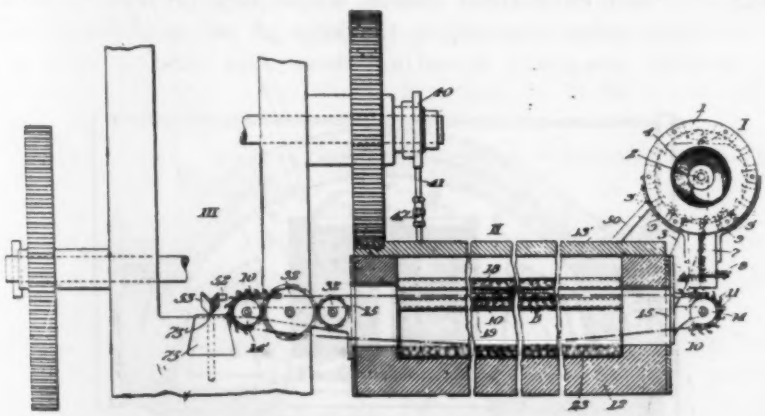
This patent describes a method of increasing the elastic limit of a hollow metal article, as, for instance, the barrel of a gun or the casing of a shell, by expanding the article beyond its elastic limit in a plurality of steps with an intermediate heat treatment between each step.

In accordance with the preferred practice, the hollow article is assembled in a die, where the amount of expansion is restrained and is expanded by an internal pressure. The article is then annealed and is again subjected to the internal expansion in a restraining die, and again annealed to relieve the expanding strains, until the desired size and elastic limit has been reached.

1,554,336, Metal Article, Otto H. de Lapotterie, of Kent, Ohio, assignor to Roy H. Smith, of Kent, Ohio.

This patent describes a method of producing rivets or other headed articles which have the characteristics and accuracy of a cold drawn shank and a head portion free from the detrimental crystal formation usually accompanying the cold forging of the head.

The method comprises drawing the stock to the size required for the shank, severing the stock cold from the blank and slightly enlarging the



head portion by cold forging. The blanks are then fed into a rotating hopper 1, from which they descend through the chute 7, with all the headed portions pointing in the same direction, and are received on the fingers 11 of a belt conveyor 10 which passes through the furnace 13′ in a manner so that the headed portions B project into the heated zone of the furnace while the shank portions of the bolts are positioned between the water jackets 18 and are kept in a cooled condition to prevent oxide and scale forming on the shank and reducing the size and accuracy thereof as when subjected to direct heat. At the point 14′ the bolt

blanks with the heated head portions and cold shanks are deposited upon the chute 53 and conveyed, shank downward, into the stationary forging die 75 and the heated heads forged to shape. The return branch of the belt conveyor passes through a water chamber 23 for cooling the conveyor.

1,555,736, Composition for Treatment of Metals, Salem Charles Wilson, of Springfield, Missouri, assignor of One-Half to J. A. Culpepper, of Eminence, Missouri.

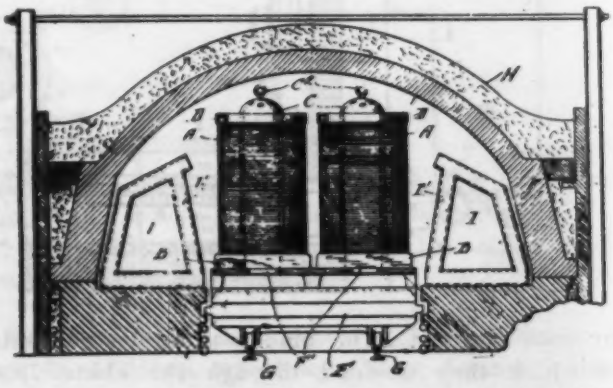
This patent describes a case hardening composition, which, when applied to iron or similar metals, imparts thereto the properties of steel.

The composition in per cent comprises, iron, 2.60; silica, 39.25; manganese, 31.05; organic matter, 8.40; undetermined, 18.70. The article to be treated is heated in an ordinary forge, electric furnace, or other suitable manner, to a high red heat and the mixture above noted is applied so as to completely cover the article which is maintained at a high red heat for a period of one to three minutes, after which it may be cooled or quenched, according to the particular requirements. The inventor states that he has produced a high grade chisel from ordinary bar iron in this way, and has been able to quickly effect the case hardening of roller bearings.

1,556,209, Method of and Means for Handling Material in Annealing, Philip D'Huc Dressler, of Cleveland, Ohio, assignor to American Dressler Tunnel Kilns, Inc., of Cleveland, Ohio, a corporation of New York.

This patent describes a means for annealing sheet metal armature punchings or other thin sheet plates which are subject to considerable surface oxidation when exposed to the heat of the annealing furnace.

The method comprises mounting these thin laminæ upon a central



core C resting upon a suitable base B and covering the same with a weight D, to hold the laminæ together. In this way, only the outer circumference A of the laminæ is exposed to the oxidizing action of the heat, while the entire sheet is being heated to the proper temperature for annealing. H indicates the tunnel furnace through which the materials being heat treated are conducted upon a suitable car F traveling upon the tracks G.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

HIGH MANGANESE STEEL CASTINGS. By J. H. Hall, metallurgist, Taylor-Wharton Iron and Steel Co., High Bridge, N. J., in *Iron Age*, October 1, 1925, page 879.

In this article the author gives the origin and properties of the 1.25 per cent manganese steel, which came into prominence during the war, and is now being experimented with in the shape of forgings, rails and in other forms beside castings. This article gives a summary of over 1800 tests on castings made during a number of years. Comparisons are also made with other steels.

MAKING BASIC OPEN HEARTH STEEL. In *Iron Age*, October 22, 1925, page 1109.

The American Institute of Mining and Metallurgical Engineers held a three-day meeting, October 13, 14 and 15, at Hotel Cleveland, Cleveland, at which time was discussed furnace design; variations in charging practice and yield; refractories and other items relating to production, quality and cost. The operating officials met without formal program but with the idea of presenting points of practice and opinion offered through assignment by a few committee members. The meeting proved well worth while.

CASTING METALS. By W. J. Reardon, in *Metal Industry*, October, 1925, page 409.

The author gives methods of eliminating difficulties with manganese bronze, nickel alloy and bearings.

DIRECT PROCESS FOR MANUFACTURE OF STEEL. By Henning Flodin, Stockholm, in *Forging-Stamping-Heat Treating*, October, 1925, page 371.

This paper was presented at the September meeting of the British Iron and Steel Institute. The author maintains that iron and steel produced from ore in one single process are superior to either open hearth or Bessemer products. The paper describes a series of experiments in the direct smelting of ore by electric means which were carried out at the Electro-Chemical Section of the Royal Technical High School at Stockholm during the years 1923-1925.

SOME NOTES OF THE FOUNDING OF LIGHT ALLOYS. By R. deFleury, Paris, France, translated from the French by Dr. R. J. Anderson.

This paper was presented at the annual meeting of the American Foundrymen's Association, Syracuse, October 5 to 9, 1925, and states that the peculiarities encountered in the founding of light aluminum-alloys are due to

the properties of aluminum and these peculiarities may be affected by impurities, by improper methods of founding and by alloying elements used. The purpose of the paper is to discuss these factors in some detail inasmuch as they are important in the kind of foundry equipment to be used and the application of the resulting castings.

SUPERHEATING IRON IN THE CUPOLA. By S. J. Felton, Cincinnati.

The above paper was presented at the annual meeting of the American Foundrymen's Association, Syracuse, October 5 to 9, 1925, and discusses the relative effects on the temperature of cupola iron of oxidation of the metal, differences between melting and freezing-range of cast iron and heat absorption by conduction, radiation, and convection. Methods of increasing the superheat of cupola metal are given.

FLOW IN A LOW-CARBON STEEL AT VARIOUS TEMPERATURES. By H. J. French and W. A. Tucker, physicist and laboratory assistant, Bureau of Standards, Washington, D. C. Technologic paper No. 296.

This report refers to elongation flow in 0.25 per cent carbon steel subjected to a fixed total load in tension at approximately constant temperature within the range 70 to 1100 degrees Fahr. The character of the flow is described, and the factors governing the selection of maximum allowable stresses are discussed. Comparisons are also given between maximum allowable stresses and the stress-strain relations determined in the customary short-time tension tests at various temperatures.

REDUCING THE COST OF CLEANING FERROUS CASTINGS. By J. H. Hopp, Chicago.

This paper was presented at the annual meeting of the American Foundrymen's Association, Syracuse, October 5 to 9, 1925, and discusses in detail the factors of shop practice which affect the cleaning operation. Molding sand together with the use of facing is stated to be one of the factors which needs the most careful attention.

PERMANENT MOLD ALUMINUM CASTINGS AND THEIR FIELD OF USEFULNESS. By J. B. Chaffe, Jr., Cleveland.

The above paper was presented at the annual meeting of the American Foundrymen's Association, Syracuse, October 5 to 9, 1925. Permanent mold aluminum castings are defined as those made by pouring molten aluminum alloys into warm metal molds with no external pressure applied to the metal. This definition is to distinguish such castings from those made by the die casting process. The author also discusses pressure die castings and permanent mold castings showing the important differences in the two processes.

X-RAY EXAMINATION OF ALUMINUM-ALLOY CASTINGS FOR INTERNAL DEFECTS. By Robert J. Anderson, Cleveland.

This paper was presented at the annual meeting of the American Foundrymen's Association, Syracuse, October 5 to 9, 1925, and discusses briefly the application of X-Ray examination to aluminum-alloy castings and gives the results of some recent experimental work.

News of the Chapters

STANDING OF THE CHAPTERS

IN the October issue of TRANSACTIONS appeared the relative membership standing of the 29 chapters of the Society as of August 1, 1925, and as of September 1, 1925. The tabulation which appears below shows the relative membership standing of the chapters on September 1, 1925, and October 1, 1925.

Standing as of October 1, 1925

GROUP I	GROUP II	GROUP III
1. Detroit (380)	1. Hartford (123)	1. Tri City (66)
2. Cleveland (360).	2. Lehigh Valley (104)	2. Rochester (60)
3. Pittsburgh (301)	3. Golden Gate (94)	3. Los Angeles (59)
4. Chicago (267)	4. Syracuse (80)	4. New Haven (54)
5. Philadelphia (252)	5. Cincinnati (76)	5. Schenectady (50)
6. Boston (219)	6. Milwaukee (75)	6. Washington (49)
7. New York (212)	7. St. Louis (63)	7. Worcester (48)
	8. Indianapolis	8. Rockford
	9. Buffalo	9. Providence
	10. North West	10. Toronto
		11. Springfield
		12. South Bend

Standing as of September 1

GROUP I	GROUP II	GROUP III
1. Detroit (376)	1. Hartford (121)	1. Tri City (65)
2. Cleveland (324)	2. Lehigh Valley (101)	2. Los Angeles (60)
3. Pittsburgh (295)	3. Golden Gate (88)	3. Rochester (59)
4. Chicago (263)	4. Cincinnati (74)	4. New Haven (56)
5. Philadelphia (256)	5. Syracuse (74)	5. Schenectady (51)
6. Boston (215)	6. Milwaukee (71)	6. Washington (48)
7. New York (209)	7. St. Louis	7. Worcester
	8. Indianapolis	8. Rockford
	9. Buffalo	9. Providence
	10. Northwest	10. Toronto
		11. Springfield
		12. South Bend

Group I—Each of the chapters in this group remains in the same position as before. All with the exception of one, show a gain over the previous report. The largest gain made by any one chapter was Cleveland with 36 new members. This gain was due, of course, to the annual convention being held in this city.

Cleveland now is 20 members behind Detroit in first place. Philadelphia and Chicago are getting rather close together, Chicago having a lead of only 15 members.

Group II—The chapters in this group all hold the same rank as last month. However, all but one show an increase in membership.

Group III—These chapters remain the same except Rochester, which now occupies position 2, taking the place vacated by Los Angeles. The other chapters, however, have membership campaigns on, which undoubtedly will have productive results and which will materially change the rating next month.

There were 101 new and reinstated members during the month, while 30 were dropped for non-payment of dues and two resigned, leaving a net gain of 69 for the month, and giving the Society a total membership of 3,451.

BOSTON CHAPTER

The annual "Get Together" meeting of the Boston Chapter was held at the Engineers' Club on Friday, October 9, 1925. Dinner was served at 6:30 p. m. in the main banquet hall of the club, about seventy-five members being present.

Following the dinner, V. O. Homerberg gave a general summary of the technical sessions at the Cleveland Convention and J. M. Darke selected three of the papers presented at Cleveland, which were of special interest to the steel treaters of the chapter and gave a short synopsis of each. C. L. Stott spoke regarding the entertainment at the convention and paid a special tribute to Prof. and Mrs. H. M. Boylston for the splendid way in which they entertained the ladies.

L. D. Hawkridge and G. C. McCormick, chairmen of the program and membership committees of the Boston Chapter, gave short talks on the activities of their respective committees.

After the business meeting, an hour's entertainment was furnished by B. F. Keith's vaudeville artists, assisted by L. G. Murray of the Boston Chapter.

The meeting was presided over by the chairman, J. M. Darke, and was under the general direction of H. B. Parker of the program committee.

H. E. Handy.

BUFFALO CHAPTER

Meeting: Thursday, October 22, Hotel Statler.

Subject: Experiences in Heat Treating—W. S. Bidle, president, A. S. S. T.

Meeting will be reported in next issue of TRANSACTIONS.

CHICAGO CHAPTER

The inauguration of the fiscal year of the Chicago Chapter was colored by the presence at the speakers' table of our national secretary, W. H. Eisenman. That very busy gentleman opened the program by

reciting the development of the chapter and the society, touching on the 1926 convention to be held in Chicago and the work that would be necessary to put it across in typical style, and finished by predicting for Chicago the greatest year it has yet experienced in the annals of the society. Following this T. E. Barker, founder member, gave his report to the chapter as their delegate to the nominating committee at the Cleveland Convention. He was glad to report the nomination to the National Board of Directors of the past and present chairman of the Chicago chapter, R. G. Guthrie. His report was quite satisfactorily received.

The technical talk of the evening was delivered by H. B. Knowlton of the Milwaukee Vocational School. His subject, The Selection and Classification of Steel, was extremely well received and excited considerable discussion at the conclusion of the lecture. Mr. Knowlton had prepared several charts on slides which were thrown on the screen to illustrate the manufacturing processes and uses of types of steels, both straight carbon and alloy. He further demonstrated the use of the spark test for distinguishing types of steel, at the same time warning his audience of the misconceptions possible from its improper application. The moral of Mr. Knowlton's talk was: Instruct the man at the fire as to the possibilities of the various types of steel and furnish him with sufficient working information with each job.

The meeting was preceded by the regular 6 o'clock dinner, held in the dining room of the City Club. Two radio stars, formerly from the Rainbow Gardens, furnished vocal and instrumental entertainment during the course of the dinner.

J. A. Comstock.

CINCINNATI CHAPTER

Meeting: Thursday, October 8, Ohio Mechanics Institute.
Subject: Salt Baths—G. C. Davis, Heat Treating Equipment Co., Boston.
No report of this meeting received.

CLEVELAND CHAPTER

The first regular fall meeting of Cleveland Chapter was held on Friday evening, October 16, in the rooms of the Cleveland Engineering Society, Hotel Winton.

The speaker was Eugene Bouton, supervisor of the time study department, Chandler Motor Car Co., and the subject was "Wage Incentive Plans in the Heat Treat Department."

Mr. Bouton called attention to the fact that although F. W. Taylor, the father of wage incentive plans, was also a pioneer in the heat treatment of steel, yet the adoption of such plans in heat treating departments had proceeded very slowly. One reason for this, Mr. Bouton said, was the difficulty in securing quality work in heat treating when using plans exactly as practiced in other departments.

A number of facts make this problem complicated, for instance, when the heat treatment work is slighted and insufficient time is allowed, the resulting defects are often not visible and, perhaps, cannot be detected

by ordinary hardness tests. In a number of automobile plants, however, wage incentive plans are being used in the heat treating departments and claims are made that these have been successful in greatly increasing production. Mr. Bouton predicted that within 10 years a great many more plants would have such plans in operation in connection with heat treating. He said that this is a problem that ought to be studied by steel treaters themselves and he believed that it could be solved by the combined efforts of the metallurgist and the time study man.

This talk brought out considerable discussion and it was evident that the subject was of great interest to those present.

At the next meeting of the chapter, to be held on Friday evening, November 20, E. C. Bain is scheduled to speak on The Use of X-Rays in Metallurgical Work. *A. S. Townsend.*

DETROIT CHAPTER

The first meeting of the Detroit Chapter of the American Society for Steel Treating was held October 19, 1925, on the fifteenth floor of the General Motors Building, this city. Dinner was served at 6:30 p. m., during the latter part of which an innovation to the Detroit Chapter was introduced. The innovation consisted of a talk on "Finger Prints" by Sergeant Stephens of the Detroit Police Department. This interesting discussion brought many points to the attention of members with which they were unfamiliar. Chief of these was the increasing commercial use of finger prints as a means of forgery protection. Sergeant Stephens believes it to be the matter of a few years until checks will all be signed (and countersigned) with a finger print.

The regular meeting scheduled at 8:15 p. m. was on "Stainless Steel." This subject was discussed by T. H. Nelson of the Ludlum Steel Company in a most interesting manner. Starting with the discovery, in a sense accidental, in which he participated, Mr. Nelson briefly outlined some factors of corrosion and the necessity of a homogeneous material to resist rusting. A brief outline of manufacturing troubles was given, illustrated with lantern slides. After this the three types of stainless material were considered, viz., chromium steel, low and high carbon; chromium-silicon alloys and the nickel-chromium group. Physical properties of the first two classes were given. In this connection, Mr. Nelson brought out the idea that on this class of material the usual tests are not typical as in automobile steels. A Brinell reading of 200 in the chromium series often resisting abrasion much better than 400 in ordinary steel. As a conclusion he offered many suggestions of the ultimate use of and substitution of ferrous alloys for non-ferrous material.

The members then participated in an interesting discussion, which brought up new points for consideration. *F. P. Zimmerli.*

GOLDEN GATE CHAPTER

The September meeting of the Golden Gate Chapter was held on the evening of Wednesday, the 16th, in the Ballroom of the Hotel Whitecotton, Berkeley. There were over fifty present, notwithstanding the distance that

many of the men from outlying plants had to come, and the meeting was an enthusiastic one.

After the regular dinner and promptly at eight o'clock, Mr. Drake, the Chairman, called the meeting to order, and the usual committee reports were followed by the first speaker of the evening, Mr. E. Little, Superintendent of the Hoover Spring Company of San Francisco. His subject was "How Automobile Springs Are Made," and he demonstrated by means of a set of springs, the various points that are of interest to every man using an automobile. His talk was followed by a lively discussion in which many of the members took part.

The next event was a resumé by Mr. C. S. Moody, metallurgist at the Caterpillar Tractor Company, San Leandro, of the course on steel given in nine sections during the past winter and spring. It was obvious a most difficult task to condense into the short space of one and a half hours the essential points of this tremendous subject, and it was the consensus of opinion that Mr. Moody made an admirable talk, bringing out the salient points in logical sequence. It was a misfortune that the lateness of the hour prevented any discussion, since there were many present who expressed their wish to ask questions and to make remarks. Everyone felt that the resumé of this subject helped to coordinate the various processes and to locate them in their proper sequence with relation to each other. *D. Hanson Grubb.*

The October meeting of the Golden Gate Chapter of the American Society for Steel Treating was held on the 14th at the Engineers' Club, San Francisco. An unusually pleasant feature was the singing of the Carl Anderson Quartet, during dinner—a surprise provided through the kindness of our chairman, F. B. Drake.

The meeting was called to order at exactly 8 o'clock, and following it the secretary's reports were made and those of the membership committee. The first speaker of the evening was introduced by the chairman. This was E. H. Kottnauer of the Industrial Service Company, whose subject was "The Classification of Steels." Mr. Kottnauer handled his talk in his usual clear and logical fashion, dealing first with the S. A. E. classification with many explanatory comments, finally with some standard specifications that are not included in the S. A. E. lists. The talk was followed by a discussion which brought out some interesting remarks from the speaker, and, as always, his efforts were greatly appreciated by the members, who felt that they were fortunate in having among them a man who is not only so well informed but with the ability of presenting his knowledge in such a clear and able fashion.

The second speaker of the evening was J. H. Gumz, of the Pacific Gas and Electric Company, whose subject was "The Industrial Use of Gas Fuel." Mr. Gumz presented a series of slides, showing the use of gas fuel in many industries with special emphasis on heat treating. A wide experience in handling the problems of the gas heating engineer made Mr. Gumz's comments on the slides of much interest.

There were sixty-two present at the meeting and they formed an enthusiastic audience. *D. Hanson Grubb.*

HARTFORD CHAPTER

The October meeting of the Hartford Chapter was held Tuesday, October 13, in the Club Rooms of the Hartford Engineers' Club, preceded by an informal dinner at the University Club. A very interesting talk on "The Manufacture of Carbon Tool Steel" was ably presented by A. W. F. Green of the John Illingworth Steel Company, of Philadelphia. The talk which was well illustrated by lantern slides of mill scenes and photomicrographs first gave a short history of the development of crucible steel by an English manufacturer of watch and clock springs, and pointed out some of the differences in English and American practice. Mr. Green stated that a good wrought iron muck bar was necessary as a base and that in his experience he had never seen a furnace charge in which all pots would show the same composition when cast individually. For this reason, in order to insure uniformity, the individual crucibles should be teemed into a ladle or molds. He explained the various types of defects such as pipes, inclusions, seams, blow holes, segregations and discussed the causes of each. Hammering will not affect the center of a bar and, accordingly, will not close up pipes as much as in pressing. Mr. Green also discussed at length, pressing and rolling operations, the effect of rolling and finishing temperatures, annealing, and heat treatment problems.

R. W. Woodward.

INDIANAPOLIS CHAPTER

In spite of the inclement weather, more than one hundred members and guests turned out Monday night, October 12, to usher in the new season and to help bring the Indianapolis Chapter farther up in the "big league" class. More than sixty of these men who came not only to increase their education in the handling of steel but also to enjoy the good fellowship of the steel men, enjoyed an excellent dinner which was served in the Y. M. C. A. auditorium at 6:30 p. m.

As every one present was very eager to learn something about steel and its heat treatment, very little time was devoted to the business part of the meeting. However, Messrs. W. L. Appel, champion golfer, W. G. Praed, our worthy chairman, Professor John F. Keller of the Purdue University, Carleton B. Edwards, W. K. Cresson and Charles M. Deere, both of LaFayette, Indiana, and numerous others were called upon to make a brief report of the Cleveland convention, which was pronounced most successful from every point of view.

Shortly after 8:00 p. m. George Davis of the Bellis Heat Treating Company, of Boston, Mass., was introduced as the speaker of the evening in place of Major A. E. Bellis, the announced speaker who was unable to be with us. Mr. Davis presented in a very able manner a most interesting paper, accompanied by lantern slides. As his subject was "Salt Baths" the discussion following the address brought forth an avalanche of questions from the men who were actually working on various tempering baths and who were eager to add to their knowledge on that important subject.

Many members and guests from Muncie, Anderson, Connersville, LaFayette and other near by cities were present for the dinner as well as the address. *C. H. Beach.*

MILWAUKEE CHAPTER

The first meeting for this year's session of the Milwaukee Chapter took place October 23 in the dining hall of the Hotel Blatz and was in the form of a very successful smoker, at which there were about 100 present. The new officers of the year were introduced to every one as well as every member to every one else, so that sociability was the keynote of the evening. Addresses were made by Messrs. Moorman, Stein and Lloyd and the discussion which followed on the subject of electrical furnaces was very lively and a number of the members gave short talks on their own experiences with them. During the evening a short musical program was rendered and cigars, cigarettes, etc., were distributed. The meeting was brought to a close by the appearance of a light lunch which was greatly appreciated by those present. *N. F. Tisdale.*

NEW HAVEN CHAPTER

The October meeting of the New Haven Chapter was held on the 16th in the Assembly Rooms of the Howard Company. Prior to the meeting dinner was served at the Cafe Mellone. The eats and other things were very good. Ask Dawless.

At the appointed time our first speaker, W. S. Bidle, our congenial National President, was introduced and he gave his usual talk concerning the society, which was full of sunshine and success.

Our next speaker was W. E. Barton, foreman of the maintenance department, Winchester Repeating Arms Company, who proceeded to roll up his sleeves and give an actual demonstration of the building of furnace arches, doors, ports, corners, mixing cement and fire clay. "Bill" Bidle became so enthusiastic that he got up and said it was the best practical talk he had ever heard at any chapter meeting, as it hit so close to home. The rest of the chapters will have to look to their laurels after that remark.

This, our first meeting of the year, was well attended, but 50 per cent of the attendance was furnished by the Howard Company, R. Wallace & Sons Manufacturing Co., Bellis Heat Treating Company, and the Geometric Tool Company. This is indeed a creditable showing for these companies, but we hope to see some of the others come to the front at the November meeting.

We were glad to see one of our new members, Edward Bahner, of the O. K. Tool Company, with us and sincerely trust that he keeps the good work up. *W. G. Aurand.*

NEW YORK CHAPTER

Meeting: Wednesday, October 21, Woolworth Building.

Subject: Manufacture and Use of Ferro Alloys—J. H. Critchett, Electro Metallurgical Company.

Meeting will be reported in next issue of TRANSACTIONS.

NORTHWEST CHAPTER

Meeting: Wednesday, October 28, Manufacturers' Club.

Subject: O. W. Potter discussed briefly the Effect of Heat Treatment on the Properties and Microstructures of Gray Cast Iron and Semi Steel. F. G. Lilygreen addressed the members on general subjects of interest. R. L. Dowdell gave brief report of Cleveland Convention. O. E. Harder presented brief discussion of Developments in Dilatometric Methods of Heat Treating.

Meeting will be reported in next issue of TRANSACTIONS.

PHILADELPHIA CHAPTER

The first fall meeting of the Philadelphia Chapter was held on the evening of September 25 and, considering that a good many of us had not fully recuperated from the strenuous week at Cleveland, vacations, etc., the meeting was well attended. For the benefit of those who were not fortunate enough to attend the National Convention, chairman Collins made a report of the convention meetings held in Cleveland during the preceding week.

The chairman announced the appointment of W. B. Coleman, the genial president of W. B. Coleman & Co., as chairman of the membership committee, and under Mr. Coleman's able guidance we look for a big increase in membership of the Philadelphia Chapter this year.

Dr. H. C. Boynton, metallurgist, John A. Roebling's Sons Company, Trenton, N. J., discussed the paper read at the Cleveland Convention by Dr. McAdam on the "Effect of Cold-Work on Endurance and Other Properties of Metals," and S. C. Spalding's paper on the "Effect of Reheating on Cold Drawn Bars."

R. H. Patch, assistant superintendent, melting department, Midvale Co., Philadelphia, discussed Mr. Sisco's paper read at Cleveland on "Electric Furnace Steel."

J. W. Harsch, research department, Leeds and Northrup Co., Philadelphia, read a very interesting paper on the "Dilatometric Method of Heat Treatment."

The Fifth Cooperative Evening Course in Heat Treatment and Metallography of Steel, given under the auspices of the Philadelphia Chapter, opened at Temple University on Monday evening, October 5, with a gratifying enrollment. The laboratory has been enlarged and the library enhanced by several new volumes.

The 1925 "Year Book" was published last month and has been pronounced a commendable piece of work by the National Office.

A. E. Donovan.

PITTSBURGH CHAPTER

The Pittsburgh Chapter held its October meeting on the evening of the 1st in the auditorium of the U. S. Bureau of Mines Building.

Chairman O. B. McMillen presided at a short business session, at which a letter of resignation as vice-chairman was read from W. J.

Priestley. Mr. Priestley has been transferred to New York, where he will be assistant general sales manager for the Electro Metallurgical Sales Corporation and in a similar capacity in the electrode division of the National Carbon Co. The chapter exceedingly regrets his leaving but wishes for his success.

After the business of the evening was completed the chairman welcomed M. A. Grossmann, metallurgist of the United Alloy Steel Corporation, Canton, Ohio, as the speaker of the evening.

Mr. Grossmann chose for his topic, "The Manufacture of Alloy Steels in Open Hearth and Electric Furnaces."

He first discussed the Basic Open Hearth furnace procedure, telling of the elimination of carbon, silicon, manganese, phosphorus, and sulphur during the melting, the rate at which these elements were eliminated and their probable combinations in the slag. He illustrated the boiling action in the bath caused by the formation of carbon monoxide gas and how the bath would quiet down as the proportion of carbon monoxide generated would decrease.

He then pointed out the resulting ingot structures of effervescent and killed steels, and the probable action of the silicon or aluminum which might be used in killing the steel.

In discussing the electric furnace, he gave its advantages, among which were the neutral atmosphere, its deoxidizing action and the ease of control, especially in holding a heat.

The practice and problems of adding alloys to open hearth heats were then discussed at some length in which each alloy was specifically dealt with.

And, in a similar manner, the addition of these same alloys to electric furnace steel was dwelt upon.

At the conclusion of this most interesting talk, a prolonged discussion was entered into by many of those present, which was of extreme interest to alloy steel makers and users. *H. A. Neeb, Jr.*

PROVIDENCE CHAPTER

On October 14, the Providence Chapter held the first meeting of the 1925-1926 season at the Providence Engineering Society Rooms, with a very good attendance of members and guests.

On opening the meeting, the chairman, J. E. Wiggins, called upon S. N. Welch, one of the members who had attended the Cleveland convention, for a few remarks and Mr. Welch had some very interesting things to say about the convention, quoting some statistics, to give an idea of the vastness of the project and commenting very favorably on the technical sessions.

F. H. Franklin next gave a brief outline of the series of lectures by Dr. R. S. Williams of the Massachusetts Institute of Technology, that are to occupy the majority of the 1925-1926 schedule of meetings of the Providence Chapter and which will consist of four informal talks on "The Heat Treatment of Steel and its relation to the Structure and Physical Properties."

"The Manufacture and Heat Treatment of Small Tools" was the subject

of this first meeting and the speaker was A. H. d'Arcambal of the Pratt and Whitney Co., Hartford.

The speaker had an unusually complete assortment of specimens, with which he emphasized the various points in his discourse, and these together with a number of interesting slides lent added value to Mr. d'Arcambal's instructive talk.

A description, which included the analysis, heat treatment, peculiarities and uses of all the tool steels (including high speed steel) ordinarily used, was first given by Mr. d'Arcambal and a broken specimen of each type, properly hardened to show the fracture was on display.

Mr. d'Arcambal stressed the fact that in order to obtain a good tool of any kind, three things were necessary:—The selection of the proper steel (and it must be good steel); the proper design and the proper heat treatment. In selecting the proper steel, he also brought out the point it was not always necessary to select an alloy tool steel for every purpose, indeed in a good many cases just as good results were obtained with a carbon steel, properly heat treated and that the only justification in using an alloy steel was in the fact that a greater hardening range was found, and this really reflected on the method of heat control and measurement used.

An interesting point the speaker made in connection with the hardening of tool steels was that if the lead pot were the heating medium used, better results would be obtained if slightly higher temperatures were employed than those used when hardening the same kind of steel in a muffle furnace.

In his talk on high speed steel, Mr. d'Arcambal brought out the fact that the low tungsten type was gradually becoming superseded by the 18-4-1 combination for general purposes and that several mills have already given up the manufacture of the low tungsten steel. He also stated that the manufacturers have recently increased the carbon content in high speed steel, thereby deriving all of the benefits accruing to the high initial quench and the 1100 degrees Fahr. draw. At this time the speaker very strongly emphasized the point that high speed steel hardened by the single treatment i. e. quenched from the high heat into a bath at 1100 degrees Fahr. was *not* as efficient as steel quenched into oil undergoing a secondary operation of drawing to 1100 degrees Fahr.

Mr. d'Arcambal took issue with those advocates, who are in favor of buying all steels by brand rather than specification claiming that while for the small consumer this would probably be the proper procedure, that for large user, equipped with the proper facilities for testing, ordering to specifications insured a better control and a better product.

Mr. d'Arcambal closed his remarks with a description of a number of sample products made by the Pratt and Whitney Co. and offered for inspection some used tools that had made some remarkable records in service.

E. J. Sullivan.

PROVIDENCE CHAPTER

The Providence chapter are to be complimented for the neat little leaflet, which they have recently prepared, giving the 1925-1926 schedule of activities.

The program for the year is as follows: On November 13, 1925, W. S. Bidle, national president, and W. H. Eisenman, national secretary, will visit the chapter. Dr. R. S. Williams, Massachusetts Institute of Technology, will present a series of lectures, consisting of four informal talks on the Heat Treatment of Steel and Its Relation to the Structure and Physical Properties. He will give the first talk on December 9, 1925, which will deal with Annealing —the Production and Properties of Ferrite, Cementite and Pearlite. On January 13, Dr. Williams will discuss Hardening, Drawing or Tempering and Toughening—the Properties of Austenite, Martensite, Troostite and Sorbite. The Providence chapter will hold a joint meeting with the Providence Engineering Society on February 2, 1926, and a subject will be offered that will be of interest to both societies. Case Hardening of Steel—the Effects of Work on the Mechanical Properties, will be the subject of Dr. Williams' lecture on March 10, 1926. On April 14th, he will talk about Alloy Steels—the Effects of Nickel, Chromium, Manganese, Molybdenum and other Elements. Instead of the regular meeting in May, the chapter will conduct a plant inspection trip to the plant of the Morse Twist Drill Co., New Bedford.

ROCHESTER CHAPTER

The Rochester Chapter held its first meeting of the year Friday evening, Sept. 25, 1925, at Mechanics Institute, Rochester, N. Y. After an informal dinner a business meeting was held. This was the first meeting under the new chapter officers. Committees were appointed and a lively program has been arranged for the year.

The yearly booklet, giving the program for the year in combination with a picture of the speaker and a short biography of his life and also a list of the local members has gone to press and will be ready before the next meeting on October 12. This booklet was originated by the Rochester Chapter and we find that several of the other chapters are following our example.

After the business meeting the Rochester Chapter heard Sam Tour's paper on Salt Baths and Their Application to Heat Treating.

The melting Point of Various Baths, Salt Mixtures, Salts Used, Decarburization of Steel in Various Salt Baths, Lead Baths and Their Use, Composition and Melting Point of Fluorides, Furnace Construction for Salt Baths, Pots Used in Salt Baths, Salts Used in Heating for Quenching, Salts Used in Heating for Drawing, Cyanide and Cyaniding, Breaking Down of Salt Baths and How to Correct it, etc., were very thoroughly explained by Mr. Tour.

In the general discussion that followed the talk, many questions pertaining to Salt Baths were asked and were completely and thoroughly answered by Mr. Tour.

There was a good attendance at both the dinner and the talk.

C. F. Wattel.

The regular monthly meeting of the Rochester Chapter was held on October 12. The meeting was preceded by an informal dinner, thirty attending. T. H. Nelson, metallurgist with the Ludlum Steel Co., and now doing field work in Conshohocton, Pa., was the speaker of the evening.

Mr. Nelson chose for his subject Stainless Irons and Steels. His talk covered the subject from the very earliest history of stainless metals up to the present day. It was in 1911 that Mr. Nelson working for Harry Brearly in England at the request of the British Government set out to find some metal for use in large gun linings that would resist the high heats and corrosive action of the acid forming gases generated. Consultation decided that chromium was the only metal that would be worthy of consideration, because of its hardness. Hundreds of heats of chromium bearing steels of varying chromium content were made up and their mechanical and chemical characteristics studied. Mr. Nelson emphasized that at this time neither he nor Mr. Brearly mentioned nor thought of "stainless metals."

The stainless properties of their alloys were discovered accidentally in this way. Mr. Nelson in a joking way offered a machined bar of one of the special alloys to a friend who was engaged in the cutlery business. This friend returned after several months with samples of some table knives that he had made and subjected to many severe tests and which were still as bright as when first made. This friend registered his name "Rust nor Stain." Harry Brearly patented his alloys and is recognized today as the first to bring forth stainless irons and steels.

Slides were used by Mr. Nelson to show the contrast between the first crucible furnaces used to experiment with and the present day 5 to 10 ton electric furnaces. Microstructures were shown to illustrate the properties of stainless ferrous metals. Production difficulties were explained, and the point emphasized that today stainless irons and steels are past the experimental stage and their high price is due to the cost of ferrochromium.

The meeting closed after a very lively discussion.

Mr. Wattel, chairman of the publicity committee, reported that by the time this meeting was reported that the Rochester booklets would be in the hands of all interested.

The membership committee is on the verge of launching a very active campaign for new members. *C. T. Wattel.*

ROCKFORD CHAPTER

The opening meeting of the Rockford Chapter of the American Society for Steel Treating was held on October 14 at the Nelson Hotel and attracted a good attendance.

The program offered included the convention report by the Rockford delegate and featured Major A. E. Bellis of the Bellis Heat Treating Company, Branford, Conn., as speaker of the evening—his subject being "Bath Hardening." Unfortunately Major Bellis could not appear in person and sent George C. Davis of Boston instead.

Speaking on the same subject Mr. Davis pointed out that all told there are some 200 variables influencing the quality of hardened tools. As far as their thermal treatment is concerned some of the variables may be eliminated by heat application in a bath—or bath hardening. The advantages to be gained were enumerated by Mr. Davis under 14 dif-

ferent headings, some of which are—no scale; freedom from warpage; uniformity of heating; uniformity of production; control of rate of heating; shorter time of exposure with accompanying increase of production; greatly lowered cost; better working conditions and a wide heat range, i. e., from 300 to 2500 degrees Fahr.

Mr. Davis endeavored to illustrate and prove his point with a number of slides, which eventually gave rise to an interesting discussion, R. Johnson, G. E. Shipman (Chicago member), J. A. Nelson, R. M. Smith and J. B. Frederick participating.

The meeting was adjourned at 10:45 p. m. Four applications for membership were received. *O. T. Muehlemeyer.*

SCHENECTADY CHAPTER

Meeting: October 27, Sirker's Restaurant.
Subject: Stainless Steel—C. B. Calloman, Allegheny Steel Company.
Meeting will be reported in the next issue of TRANSACTIONS.

ST. LOUIS CHAPTER

The October meeting of the St. Louis Chapter was held on the evening of the 16th at the American-Annex Hotel.

In place of Major Bellis, president of the Bellis Heat Treating Co., who was scheduled to address the meeting, was Mr. G. C. Davis of the same company. Mr. Davis was for three years secretary of the Boston Chapter and before the meeting had gone very far demonstrated to all those present that he knew what steel treaters wanted to hear.

Preceding the meeting an interesting announcement was made; W. T. Remmers, one of our members, will instruct a class in heat treating at Washington University, every Wednesday evening after the first of the year. The coming schedule and the new members were announced to the members. Short talks on the Cleveland Convention were delivered by Messrs. C. B. Swander and F. G. White.

Mr. Davis' address, the main event of the evening, dealt with "Heat Treatment in Salt Baths," illustrated with lantern slides. The various kinds of salts were described and the type and arrangement of the furnaces. It has taken years of experiment to iron out the difficulties of furnace design, style and kind of pot, proper mixture of gas and air, to make the use of salt baths most efficient. The members and guests heard of the great increases in production in wire annealing, tool and die hardening and drawing from the use of salts. The graphs showing the rate of heating in the oven furnace, in lead, and in salt baths were very enlightening. Perhaps the most important point brought up in this most interesting paper was the new light on the nature of high speed steel hardening, that salt bath heating has brought out. This new conception will lead to greater and more uniform production from tools, the elimination and the more efficient use of labor. Discussion lasted long after the formal closing of the meeting. *Alan Jackman.*

SYRACUSE CHAPTER

The Syracuse Chapter of the American Society for Steel Treating held its regular monthly meeting on October 12 at the Onondaga Hotel. After a good dinner in the Coffee Room of the hotel, we listened to our president, W. S. Bidle, who talked about our national organization, and to the speaker of the evening, Dr. S. L. Hoyt of the research laboratories of General Electric Company who spoke on the metallography of iron and steel.

Dr. Hoyt very ably in the short time allotted to him discussed the iron-carbon diagram, what it meant, and how to interpret it. He explained that the lines in the diagram may be considered as the boundary lines of areas in the same way as the lines on a map are considered as boundary lines of states. He took us over two routes from the molten state to the ferrite plus cementite state, the first being the 2.00 per cent carbon route and the other the 0.80 carbon route. The various constituents discussed were illustrated by slides of photomicrographs. Dr. Hoyt introduced us to some new lines in the lower left hand corner of the diagram which concern two new forms of iron, epsilon and eta, discovered by Dr. Hanemann of Germany.

We all enjoyed this talk on the fundamentals of metallography.

P. Peskowitz.

TRI-CITY CHAPTER

The September meeting of the Tri-City Chapter was held at the Davenport Chamber of Commerce, with R. G. Guthrie of the People's Gas, Light and Coke Co., as the principal speaker of the evening.

Mr. Guthrie spoke on Elementary Metallography. He explained the use of the microscope in the inspection and examination of steel. Mr. Guthrie's talk brought out an unusual amount of discussion and the meeting was not adjourned until a very late hour.

Before Mr. Guthrie talked, the chairman, Mr. Burgston, announced that our past chairman, Mr. Bornstein, had been nominated for a director of the National Society. This announcement was the cause of much rejoicing, as every one that knows Mr. Bornstein, and has followed the work that he has done for this society, feels that no better selection could have been made.

Several members then gave short talks on the convention. These talks were of great interest to the members that were unable to take in the big show.

We also had the pleasure of having Mr. Felding and four other members of the faculty of the Iowa University of Iowa City, with us at this meeting.

C. F. Scherer.

WASHINGTON CHAPTER

The first meeting of the 1925-1926 season of the Washington Chapter was held October 16 and was addressed by A. N. Connaroe, chief chemist

of the National Malleable and Steel Castings Company, on the subject of "Heat Treatment of Steel Castings." The talk was based largely upon Mr. Connaroe's experiences in the production of railway car couplers from basic open hearth metal, using a 100 per cent cold charge. The magnitude of the operations with which the speaker has been associated may be gathered from the statement that his company produces 40 per cent of the entire production of the United States in this commodity.

Following a short but extremely clear description of the manipulation of the basic open hearth furnace and the chemical reactions that proceed at various stages of the process, attention was given to the initial structure of steel castings as affected by the rate of cooling from the molten state to room temperature. The latter in turn is governed by the pouring temperature, the character and temperature of the mold, the size and form of the casting and the time at which the casting is shaken out of the mold. Marked ingotism will result from any combination of these factors which is productive of an extremely slow cooling rate.

The four different classes of heat treatment used in the preparation of finished castings, namely, annealing, normalizing, quenching and tempering, and case carburizing were next considered, mention being made in each instance of the usual applications of the particular method. Considerable attention was given to the design and operation of heat treatment furnaces from a viewpoint of uniformity of temperature, economy of fuel and minimization of oxidation. In the study of heat treatment work pyrometer location becomes an important factor. Cleaning prior to annealing is also important, in that it increases the rate of penetration of heat into the metal.

Mr. Connaroe completed his talk with a description of an exceptionally complete and interesting series of photomicrographs, illustrating various structural features produced by different melting and casting practices and heat treatment operations. Of particular interest was his discussion and illustration of the various forms of inclusions in cast steel, their origin, and their effect upon the ultimate physical properties. He described the precipitation, during cooling, of ferrite upon sonims of manganese silicate, as taking place readily because these two substances crystallized in the same system. Mr. Connaroe considered that submicroscopic sonims present in these segregated areas support the ferrite under applied stresses and are, therefore, the cause of the increased elastic limit and tensile strength observed in materials in which such segregation is pronounced. A peculiar defect described by Mr. Connaroe was the curved grains frequently found near the gate of a casting; these are due to the metal entering in a swirl and depositing non-metallic particles along curved paths, their positions being then maintained by the rapidly solidifying metal. The grain boundaries being filled with these small inclusions, heat treatment was unable to affect them, although it could improve the physical properties of the interior of each grain.

An extended discussion followed Mr. Connaroe's paper, in which many of the chapter members participated, this discussion centering around heat

treatment problems, the use of addition agents for purposes of deflocculation of sonims, and the various types of porosity so frequently appearing and disappearing without apparent cause in practically every foundry.

Jerome Strauss.

WORCESTER CHAPTER

The first meeting of the 1925-6 season was held Thursday evening, October 1, at the Wickwire Spencer Cafeteria, 80 Webster Street. A chicken supper was served to twenty-five members and guests at 6:30 P. M.

Mr. Searle, chairman of the local chapter, opened the meeting with a few remarks on the progress and aims of the Chapter. He also made brief mention of the progress which had been arranged for the following meetings.

Mr. Phelon, Worcester delegate to the National Convention, next gave a talk on the happenings at the Convention.

Mr. Hillman, founder and first chairman of this chapter, next discussed some of the papers presented at the Convention, particularly acid versus basic open hearth steel, the advantages and disadvantages of trade names vs. chemical specifications for tool steels in the shop, and the origin and cause of soft spots in carburized steel. He also described the new features in furnaces which were exhibited in Cleveland. At the close of Mr. Hillman's remarks, lively discussion took place until the meeting ended at 9:45 P. M.

E. D. Clark.

The regular October meeting of the chapter was held at the Winter Garden of the Hotel Warren, Thursday evening, October 15. Forty-five members and guests attended the supper which was served at 6:30 P. M.

The chapter had as guests for this meeting W. S. Bidle, president of the American Society for Steel Treating, and W. H. Eisenman, secretary of the society.

Mr. Searle, the local chairman, first called upon Mr. Eisenman, who presented to the members some very interesting facts concerning the society's growth, aims and work. Mr. Eisenman mentioned in particular the great progress which the society had shown in its six years of existence; the healthy condition of the chapter's treasuries and the type of men who are members. He mentioned that the aim of the society now was to create good will among the officers of manufacturing plants; bring to their attention the good that the society is doing for them directly through men in their plants belonging and in this way creating a secure backing of friendship and help, which was much more valuable to the society than merely a large number of members.

Mr. Bidle next addressed the members, choosing as his subject "Impressions." This subject is the result of a great number of plant visits, particularly automobile makers, accessory makers, forge shops, machine tool makers, etc., thereby seeing how others meet their heat treating problems. The most important piece of equipment is the furnace and Mr. Bidle discussed the great numbers which he had seen, illustrating with diagrams the novel schemes which were used.

Packard, Dodge Brothers, Studebaker and Hudson heat treating plants were described and discussed; how Ford heat treats one thousand tons

of material daily, and his rotary quench tool room equipment of the smaller type which was in general use was also described.

Mr. Bidle stated that macro-etching of steel, which had not been used to a great extent in years past, was being used more and more as a means of detecting trouble.

In summarizing, a majority of the work, especially if heavy, is heat treated with oil as a fuel. Natural and city gas is used to an extent in the smaller work and electricity for heat treating is making rapid progress. Continuous and automatic furnaces are rapidly replacing ordinary furnaces on account of the greatly increased production and uniformity of results. Rotary furnaces for carburizing are used more and more in certain types of work, replacing the box method of packing. Cyanide used as a heating medium, thereby eliminating scale and producing clean work, is used in hardening carburized work.

At the conclusion of Mr. Bidle's talk questions were answered, showing that those hearing the subject presented in such an entertaining manner were greatly interested.

The meeting closed at 10:30 P. M. The executive committee met directly after and discussed its problems with Mr. Bidle and Mr. Eisenman until 11:15 P. M.

E. D. Clark.

NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member: A represents Associate Member: S represents Sustaining Member: J represents Junior Member: and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ALDRIN, P. R., (M-10), works manager, St. Louis Forgings Co., 21st & Southern Railway, East St. Louis, Ill.

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BARTH, J. J., (M-9), Barth Stamping & Machine Works, Cleveland.

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WELDING STEEL TUBING AND SHEET WITH CHROMIUM-MOLYBDENUM WELDING WIRE

By F. T. Sisco and H. W. Boulton

(Discussion Continued from Page 620.)

steel containing vanadium should be done in an experimental way to a considerable degree before such welds are put in service. It may be that heat treatment will remove the brittleness.

Reference is made to the localized annealing that occurred in the chromium-molybdenum tubing. This localized annealing appears not to have been examined under the microscope, as the pieces examined extended only about ¼ inch from the weld. This same action occurs in any piece of steel. It is evidently due to the time and temperature being such as to produce the greatest ductility. In the case of plain carbon steel about ¾ inch thick, it occurs at a point about 1⅛ inches from the line of the V, and is characterized by a refinement of grain much exceeding that of the original material.[1]

Fig. 22 shows what seems to be a crack or similar defect, possibly lack of fusion. The writer's experience leads him to suggest the necessity of examining welds both unetched and etched, using at least 500 diameters, and in case of doubt, still higher power. Very light etching is often valuable, especially when the structure is confused or complicated, as it brings out defects that the usual etching masks.

Also a weld usually reacts differently to any etching reagent than does the base metal, and often another reagent is required to get the best results. So it is advisable to experiment both with various reagents and with the times of their application. Generally slow acting solutions are best, and in the writer's experience nitric acid in any form is particularly objectionable. Picric acid in either ethyl or amyl alcohol is much better for general use, but the various special solutions are sometimes of great value.

This paper is the first one that has come to the attention of the writer in which accurate information is given as to the welding of alloy steels, and in view of the possibilities of their use in air craft, it is to be hoped that the authors will continue their work and meet with still greater success, because welding, in the writer's opinion, when used under proper procedure and control, will solve many of the annoying problems in connection with joints on air craft.

Written Discussion:—By J. B. Johnson, McCook Field, Dayton, Ohio.

The results of the investigation by the authors appear to warrant the conclusion that a chromium-molybdenum steel welding wire can be used as successfully as a low carbon steel welding wire for welding chromium-molybdenum tubing. Additional results obtained at the Engineering Division would indicate that the chemical analysis of the tubing may modify this conclusion, in fact, render questionable the use of a chromium-molybdenum steel welding wire for unheat-treated parts unless the analysis of the tubing is carefully controlled.

A series of welding experiments were made on a chromium-molybdenum

[1] Fusion Welding, S. W. Miller, Year Book, American Iron and Steel Institute, 1921, p. 315.

tubing of the following analysis:

	Per Cent
Carbon	0.27
Manganese	0.80
Chromium	0.86
Molybdenum	0.12

This differs from the analysis used by the authors in that it has a higher manganese and lower molybdenum content.

Specimens of tubing were welded with the oxy-acetylene flame, using low carbon and chromium-molybdenum steel wire from the same stock as that used by the authors. The welding was done by the same welder.

The results are given in Table I.

Table I

Chromium-Molybdenum Steel Welding Wire

Tubing—1 x 0.058 inch	C 0.27	Mn 0.80	Cr 0.86	Mo 0.12
Yield Point, pounds per square inch....	82,700	79,600	82,100	82,500
Tensile Strength, pounds per square inch	83,450	79,600	94,500	90,400
Elongation, in 2 inches per cent	1.5	.....	2.5	2
Tube	**C 0.32**	**Mn 0.56**	**Cr 0.92**	**Mo 0.23**
Yield Point, pounds per square inch....	90,000	89,400	87,600	.....
Tensile Strength, pounds per square inch.	106,700	115,400	110,400	.....
Elongation, in 2 inches per cent.....	7	6	6	.....
Location of fracture.....		¾ inch from weld		
Low Carbon Steel Welding Wire				
Yield Point, pounds per square inch....	90,100	93,050	.....	.....
Tensile Strength, pounds per square inch.	115,700	118,700	.....	.....
Elongation, in 2 inches per cent.....	5.5	5.5	.....	.....
Location of fracture.....		¾ inch from weld		

The fractured test specimens and the structures as revealed by the microscope indicate a much coarser grain in the welds formed by using chromium-molybdenum welding wire and the high manganese tubing when compared with similar welds in the low manganese tubing. The former have lower strength and less ductility with a very unusual fracture for a butt welded joint in thin-walled tubing. The low carbon welds in the high manganese tubing compare favorably with those reported by the authors on the low manganese tubing.

E. E. THUM: We recently made a study of the amount of welding which is being done in aircraft production. I do not have the figures directly in mind, but it may be interesting to those present to know that aircraft production in the United States is now verging on "quantity production." There are at least two factories which are turning out ships at the rate of so many per day rather than so many per month or so many per year, as was true only a short time back. The amount of welding going into these ships

is consequently considerable, and the questions raised by the Army Air Service therefore are far from being academic. The bulk of the commercial ships being built are made with steel fuselages, that is, the skeleton work is of cold drawn plain carbon steel tubing. The alloy welding job described by the authors is somewhat special to Army Aircraft.

As an instance of the care and inspection under which this welding work is done, I may cite the latest design of Liberty motors which are going into these ships. The water jacket is welded to the outside of the cylinders, and the computed stress on these water jackets is in the neighborhood of 14,500 pounds per square inch at the joint. As far as I know, there have been no failures occurring in these welded joints to date. Another aircraft manufacturer in the vicinity of New York has produced over one hundred ships with all welded metal skeletons in the fuselage. I believe to date they have had something like three crashes and so far they have not yet found, even under severe accident, any failure in the joints. Consequently, I bring these points to mind showing that the welding of alloy steel frames on aircraft is far from being an academic problem at the present time, but is a problem which is quite capable of solution when proper attention is given by the management.

Author's Closure

The writer wishes to thank Mr. Miller for his discussion of the paper on welding steel tubing. He was much interested in Mr. Miller's statement that a molybdenum content exceeding 0.35 per cent is responsible for bad welding properties, due to a heavy, infusible slag. This was not apparent in the experiments on the tubing and sheet. Although the welding wire contained 0.95 per cent molybdenum, it worked very well under the torch. Of course the sections welded were very thin which may have been a factor in producing a satisfactory bond.

In the time available for the investigation, it was not possible to determine the quality of the material in the weld by machining off the excess metal at the weld. The investigation of this phase would have been interesting and probably instructive, but was not considered necessary as the point of the investigation was solely to compare the strength of welds made with chromium-molybdenum wire with welds made with standard low carbon welding wire in order to adapt the former, if possible, to aircraft construction.

In the metallographic work all of the specimens taken were carefully examined before etching. No oxide, dirt, or other foreign matter was noted in any of them. In Fig. 22 to which Mr. Miller refers, the dark line running vertically in the photomicrograph is not a crack. It was not apparent in the unetched specimen. It is probably a line of demarcation between the metal in the sheet and the metal in the weld, and was undoubtedly caused by a failure to obtain perfect homogeneity of structure in heat treating.

Mr. Miller states in his discussion "that the welding of any steel containing vanadium should be done in an experimental way . . . . before such welds are put in service." The writer might say that in aircraft construction fittings of welded chromium-vanadium steel sheet are extensively employed. For these fittings chromium-vanadium steel is ordinarily much superior

to plain carbon steel both in the ease by which it is welded and in the resulting physical properties. The welds are made with standard low carbon welding wire.

In the metallographic work alcoholic nitric acid was found to be the only suitable etching reagent. The specimens examined were very small (0.036 inch thick), hence it was necessary to mount the specimen in solder to facilitate polishing and microscopic examination. It was found that when alcoholic picric acid was used, some of the reagent would creep down between the specimen and mounting. Thorough washing in hot water would not remove it. When the specimen was inverted on the stage of the microscope a little of the picric acid would run out and stain the polished surface. Much effort was expended in trying to etch with picric acid but without success, hence it was necessary to use alcoholic nitric acid exclusively.

In regard to Mr. Johnson's discussion, no comment is necessary. One of the authors (Mr. Boulton) cooperated with Mr. Johnson in his work on the high manganese steel tubing. Mr. Johnson shows conclusively that a high manganese content is responsible for inferior physical properties in the welded section. This is especially evident when welded with chromium-molybdenum welding wire.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

CHEMIST METALLURGIST is desirous of changing positions. Has had 10 years' experience in chemical analyses, physical testing, microscopical work and heat treatment of machine tools, dies, forgings and carbonizing. Salary nominal. Prefer permanent position with future, in Cleveland district. Address 11-20.

METALLURGIST CHEMIST with 14 years' experience in the metallography, heat treating, physical testing, analysis and manufacture of the non-ferrous alloys desires position. Experience also embraces the steel industry, including alloy steels and the ferro alloys of vanadium, tungsten and molybdenum. Past 10 years employed as an executive. Desire a change for reasons over which I have no control. Address 11-35.

METALLURGIST with nine years' experience in testing, analysis, heat treatment and metallography of automotive materials, desires position with established concern. Address 11-15.

METALLOGRAPHIST-METALLURGIST desires to change position. Graduated from German University, with 3 years' experience in metallography, heat-treating, hardening and inspecting; also knowledge of physical testing. Address 11-10.

TOOL HARDENER desires position. Has had three years' experience dressing all kinds of tools for pneumatic hammers. Address 11-45.

METALLURGIST AND CHEMIST desires position. Has had 6 years' experience in steel plant chemical laboratory on miscellaneous work and 3 years' experience as metallographist, as well as experience in research, testing, heat treatment and inspection. Can furnish excellent references. Address 10-15.

CHEMIST with 8 years' experience in ferrous, non-ferrous alloys, analysis, also metallographic experience, desires position. Capable of taking charge of laboratory. Excellent references. Address 10-10.

POSITIONS OPEN

WANTED: A $10,000.00 salesman to represent a prominent heat resisting alloy manufacturer in Detroit and adjacent territory. Send full information regarding present employment, experience and education. Address 11-30.

SALES REPRESENTATIVES wanted by manufacturer of industrial oil burning appliances. The line is well established and has an enviable reputation in all fields. Consideration will be given only to high grade men who have clientele among metal working industries. Give full particulars in first letter. Address 11-5.

POSITIONS OPEN

WANTED: Young men of exceptionally fine personality and most dependable character and with experience in the use and maintenance of instruments, gauges, meters, pyrometers, recorders and controlling devices, to qualify and train for positions as traveling service engineers and field investigators. Must be free for unlimited traveling and transfers. Exceptional opportunities for broad experience and promotion to responsible positions. Write stating age, education, experience and salary desired. Address 11-25.

WANTED: Three salesmen, one each for Wisconsin, Michigan and Illinois. Our product is imported Swedish iron, hot and cold rolled, and genuine Swedish tool steel. We believe the right man has a splendid future. Address 11-40.

WANTED—High grade young man by long established manufacturer of measuring instruments and temperature controlling equipment to qualify as sales engineer specializing on applications for temperature measuring and controlling instruments in heat treatment processes and similar work in the metal manufacturing industries. Preference given to candidates having had experience in use and maintenance of temperature measuring instruments and educational advantages in engineering or metallurgical lines. Must be free for unlimited travel. Write, stating age, education, experience and salary desired. Address 10-20.

WANTED—Young man for production work in high-class repair laboratory for measuring instruments and controlling devices. Wonderful opportunities for promotion to executive positions offered for right man. Individuals having had experience in actual repair work in laboratories for gas or electric meters will receive special consideration. Opportunity offered to receive special training course in factory laboratories of well-known manufacturer in preparation for promotions in branch repair laboratories. Write, stating age, experience, education and salary desired. Address 10-25.

WANTED

WANTED—Second hand, Hardness Testing Machine. Rockwell or Brinell preferred. Must be in good condition. State make, model, condition and best cash price. Address 10-5.

FOR SALE

FOR SALE—Used Brinell Machine. Write Boston Gear Works, Norfolk Downs, Mass.

FOR SALE—Commercial heat treating plant doing fairly good business. This is a good opportunity for a practical man. Philadelphia district. Address 10-30.

Items of Interest

BELL & Gossett Company of Chicago, long, well and favorably known throughout the trade as purveyors of a high grade line of heat treating materials and equipment, have just announced the establishment of a general industrial instrument department which will pay particular attention to the engineering phases of pyrometer installations.

To head this department the company has secured the services of C. C. McDermott, who is exceptionally well known throughout the industry. Mr. McDermott began his experience with the Brown Instrument Company in their factory at Philadelphia. Following two years in charge of their Philadelphia territory he was placed in charge of the Chicago territory.

Following four highly successful years in this responsible position he joined the organization of the Republic Flow Meters Company where he was in charge of the pyrometer division.

Mr. McDermott was largely responsible for the design and development of Republic pyrometers and from these facts the trade will be assured of a most exceptional engineering service at the direction of Mr. McDermott.

Associated with Mr. McDermott is R. E. Soules. Mr. Soules has been with the Bell & Gossett Company for several years as a pyrometer specialist and this personnel is being ably supported by the company's liberal policies, so that the future of the new department is exceedingly bright.

In this connection the company announces that large stocks of complete thermocouples of the various elements commonly used as well as protecting tubes of the better known materials will be carried at all times.

This development of the business marks another distinct step forward in their progress which has been very consistent since the inception of the company. So steady has been this progress that the company found it necessary to erect a new and larger factory building. This building was especially designed for the company's production and is considered an ideal plant of its kind. The new plant is located at 3000 Wallace Street, where the company's executive offices and engineering departments, as well as production departments, are nicely coordinated under one roof.

Charles F. Green, chief chemist and assistant treasurer of the Henry Souther Engineering Co., Hartford, Conn., died at the Hartford Hospital, October 11th, following an operation for appendicitis. Mr. Green entered the employ of the Henry Souther Engineering Co. shortly after graduating from the University of Pennsylvania in 1914, and after practical serv-

NEW FISHER POLISHING MACHINE

An independent unit for preparing metal surfaces with which separate heads can be used so that the same machine may be used for either fine grinding or for polishing.

The polisher consists of a vertical motor with a polishing disc directly connected to the motor shaft. Motor is mounted on a circular cast-iron base which has three (3) legs and holes for attaching to a table. Mounted on the base, and surrounding the motor, is a cylindrical nickel plated brass housing. On top of this housing is bolted a nickel plated copper bowl which completely surrounds the polishing head. This bowl is provided with a drain which draws off the polishing liquid caught in the bowl. It is also provided with a nickel plated copper cover which protects the disc from dust, when not in use.

It has a 6 inch polishing head of finished cast iron with hard rubber disc on top, for holding the polishing felt. A special counterbalanced clamping device enables the operator to quickly attach or remove the felt.

The motor can be operated on either 110 volts A.C. or D.C.; normal speed about 1700 r.p.m.

Outfit supplied with polishing head and felt disc; with cord, pendent-switch and plug. **Each, $95.00**

FISHER LEVIGATED ALUMINA

for Metallographic Polishing

This alumina is now recognized by the leading metallographists as the most satisfactory material for polishing metal surfaces for microscopical examination and photography, and is recommended in the newer text books on this subject.

FISHER ALUMINA. Grade No. 1. For all hard metals. One ounce with 50 ounces of distilled water makes the correct polishing solution. **Per ounce, $1.00**

FISHER ALUMINA. Grade No. 2. For medium hard metals. Especially suitable for cast iron bronze, brass and all nickel and copper alloys. One ounce makes 100 ounces of correct polishing solution. **Per ounce, $1.40**

FISHER ALUMINA. Grade No. 3. For very soft metals and other metal specimens for investigation under highest possible magnifications. One ounce makes 150 ounces of correct polishing solution. **Per ounce, $1.80**

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"Everything for the Laboratory"

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ice in foundries and brass mills, became chief chemist in 1918 and assistant treasurer in 1923. He was a member of the American Chemical Society, American Society for Steel Treating and the Hartford Engineering Club.

The Brown Instrument Company, Philadelphia, has announced the opening of the following offices: Indianapolis, 215 East New York St., J. R. Green, in charge; Cleveland, Room No. 1108 Hippodrome Building, G. S. Frazee, in charge.

John McConnell, formerly vice-president in charge of operations of the United Alloy Steel Corporation, Canton, Ohio, has joined the organization of the Donner Steel Company, Inc., Buffalo, in a consulting and advisory capacity.

J. W. Griffiths, recently connected with the Bethlehem Steel Company as superintendent of open hearths, has established himself as a consultant with companies experiencing difficulties in special steel manufacture. His address is 1306 Twelfth Street, N. W., Canton, Ohio. Mr. Griffiths has been in the steel industry for 25 years, formerly having been with the United Alloy Steel Corporation, Canton, Ohio, and the Central Steel Company, Massillon, Ohio.

Paul Llewellyn, formerly vice-president in charge of sales, Interstate Iron & Steel Co., Chicago, was elected, effective Sept. 29, to the office of president of the company to succeed his father the late Silas J. Llewellyn. Mr. Llewellyn received his education at Mercersberg Academy, and at the Sheffield Scientific School of Yale University. In 1908 he entered the service of the Interstate Iron & Steel Co. at its Cambridge, Ohio, plant and two years later was placed in charge of operations. He was made assistant works manager of the East Chicago works in 1912 and became manager of that plant in 1914. Two years later his responsibilities were enlarged by having the management of the South Chicago works placed with him. In 1918 he entered the service of the United States Army as a captain in the procurement department of the Chemical Warfare Division and in September, 1918, he was promoted to major. Upon being discharged from military service he entered the sales department of the Interstate Iron & Steel Co., and in 1921 was elected vice-president in charge of sales, which position he held until his recent election to the presidency.

Plans for the immediate erection of a large warehouse and office building at Santa Fe Avenue and Fifty-second Street, Los Angeles, Cal., by the General Electric Company, have just been announced. The plant, which is to be used as a distributing center, will cost about $1,000,000, including land, buildings and equipment.

The plans being prepared by the Austin Company of California, call for a warehouse three stories high and designed to handle four additional floors. The warehouse besides housing handling machinery to move the stock will include a cafeteria for employes.

The office building will adjoin the warehouse, fronting on both Santa Fe Avenue and Fifty-second Street, and will be two stories high. One of the

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Composition is but one factor in the making of Permanent Magnet Steels. Thermal treatments before the steel goes to the customer are governing factors in obtaining proper values in finished magnets.

Simonds magnet steels are furnished in both Tungsten and Chromium grades in sheets, strips or bars. When required in the annealed condition, a special anneal is given, depending on the method of magnet manufacture. This anneal, while softening sufficiently to allow of cold working or blanking, is so regulated as to prevent loss of magnetic properties. Ordinary annealing will lower perceptibly these important values.

We maintain a magnetic testing laboratory for our own development work and to co-operate with our customers in helping them to produce a product of the highest quality. This service and our experience are available to those interested in producing high grade permanent magnets for meters, magnetos, radio work and the like.

We welcome the opportunity to improve your product, and to solve any of your present problems.

SIMONDS STEEL MILLS

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outstanding features of the office building is that it will be heated by electricity. Numerous departments of the General Electric Company at present are scattered over the city, but as soon as the leases on the places expire they will be moved to the new central location. The building is expected to be ready the first of the year.

S. A. Harris, formerly with the James H. Herron Company, consulting engineers and later metallurgist with the Bourne Fuller Company, has recently associated himself with the Steel Improvement and Forge Company, Cleveland, in the capacity of chemical and metallurgical engineer.

The Central Steel Company of Massillon, Ohio, has recently prepared a very convenient and adjustable table of the S. A. E. steel specifications, the Central Steel Company's Uma series of steels together with the proper heat treatment for each of these materials.

The table is in the form of 3 celluloid circular discs about 3½ inches in diameter, the discs being fastened together and pivoted at the center so that they may be oriented to obtain the desired information. This celluloid table should be very helpful to buyers, metallurgists, heat treaters, etc., and may be obtained by addressing the Central Steel Company at Massillon, Ohio.

John Wiley & Sons, Inc., New York City, have recently published a book entitled, "Physical Metallography," by Prof. Dr. Ing. Ehr. E. Heyn, Geh. Reg. Rat, late director of the Kgl. Materialprüfungsamt and of the K. W. Institut für Eisenforschung. This has been translated from the German and somewhat augmented by Marcus A. Grossmann, metallurgical engineer, United Alloy Steel Corp., Canton, Ohio. The multiplicity of sciences involved in metallography is emphasized in this volume. Mr. Grossmann's aim in translating this work was to present accurately the conceptions of the author, whose methods of investigation laid the foundation for many advances in metallography, and whose views were often so far in advance of his day that they are only now finding general recognition. The author laid the greatest stress on the diversity of knowledge involved in a thorough study of metallography. The book contains ten general chapters, the titles of which are General Survey of Metals and Alloys; Developments during Freezing and Cooling of Alloys-Transformations; Method for Determining the Equilibrium Diagrams; Structure of Metals and Alloys and Observation of the Structure; Properties of Strength and Hardness; Metallic Substances and Gases; Shrinkage and its Attendant Phenomena; Magnetic Properties; Electric Conductivity; and Steel.

John Wiley & Sons, Inc., New York City, have recently published a book entitled, "Materials Testing—Theory and Practice," by Irving H. Cowdrey, assistant professor of testing materials and Ralph G. Adams, instructor in mechanical engineering, Massachusetts Institute of Technology.

The experience of the authors in college and technical evening school has led them to conclude that general principles are basic and fundamental and are of assistance in the widest application, while specific terms of information are often superficial and sometimes narrow in their application. This has led the authors to prepare this book, which may be used as a test to accompany a laboratory course in the study of materials under stress, rather than a laboratory manual. They have not outlined in detail any particular series of tests or experiments but have given basic methods. This, they believe, will show the important principles upon which the great mass of specifications are based.

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